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Neural Basis of Theory of Mind: An eye gaze preference task.

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Supervisor: Dr. Sharon Abrahams.

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Abstract

This study considers the speculation made by previous researchers that 'Theory of mind' (ToM) could have a neural basis. ToM refers to our capacity to make inferences regarding other individuals' mental states and it is vital to how we function within the social world. This research is a pilot study to assess if a ToM eye gaze preference task can be administered within the confides of an MRI scanner with a secondary aim of considering which brain regions could govern our ToM processes. The task was first administered to healthy controls within a pilot study to ensure that the required responses could be produced within certain time constraints. Satisfactory results then meant the task could be implemented in an fMRI study which was designed with the same time restraints as seen in the pilot study. Within this study healthy controls had different BOLD responses when comparing the ToM task against a control task within the Hippocampus, Insula and the Superior Temproal Gyrus. Further variations were found in the Inferior Parietal Cortex, the Amygdala, the Insula and the STG when comparing the neural responses found in the ToM condition to neural responses exhibited in the the favourite condition. In conclusion the main aim of the study was to implement and pilot a ToM eye gaze preference task into a novel imaging environment, this study has successfully completed this and therefore the task can be utilised within future brain imaging studies perhaps considering various clinical populations.

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1. Introduction

1.1 Social Cognition

In 1968 Dr. M. Harlow transcribed the details of a young man whom following a horrific brain injury was described as being "changed in the mind" (Damasio, Grabowski, et al., 1994; Wilgus, 2009). It was reasoned at this time that the young man had alterations within his personality and behaviour, with hindsight the 21st century diagnosis would be that he is suffering from a deficit within his social cognition. The term social cognition not only involves the concepts of personality and behaviour within its definition but also refers to a substantial about of information required for the cognitive processes and abilities that help us to navigate the social world in a culturally and socially acceptable manner (Overwalle, 2009). Therefore social cognition is how we survive in our social world and involves the processes of perceiving, interpreting and acting on social information (Adolph, 2001; Pelphrey, Adolph & Morris, 2004). This ability is quintessential a human aptitude which refers to the fundamental abilities which allow us to interact with other humans (Adolph, 2001; Pelphrey, Adolph & Morris, 2004). Brothers (1990) explains how social cognition is the accumulation of accurate perception of the disposition and intentions of other individuals. Whilst Carrington and Bailey (2009) extend this definition by adding, that it is our ability to understand people via facial expressions, eye gaze, body posture and social linguistic factors such as prosody and the social content of speech. Essential social cognition allows us to make inferences of transitory states (goals and intentions) and inferences of enduring characteristic (personality traits and social scripts) (Carrington et al., 2009).

It is apparent that social cognition encapsulates a wide scope of information and processes and is the driving power behind our social interactions with the world. The present study shall concentrate on one aspect of social cognition, the concept in question contributes substantial to the definition and process of social cognition (Overwalle, 2009) and is known as 'theory of mind'(ToM) or mentalising.

1.2 Theory of Mind

'Theory of mind' is an automatic, high level and almost without exception a human function (Overwalle, 2009). The basic definition illustrates that theory of mind is our ability

to explain and predict the behaviour of ourselves and others by attributing mental states to them, such as beliefs, desires, emotions or intentions (Premack & Woodruff, 1978). Hence it allows us to understand another's desires and intentions are distinct from our own. The idea originated from primatologists who described how it was possible that chimpanzees understood certain mental states in other chimpanzees (Brothers, 1990).

In recent years the definition for this aptitude has evolved and evidence has been placed forth arguing for the concept to be defined as two components. Evidence for this is reflected in individuals who are known to have impairments in their mentalising abilities within everyday life, but can still complete particular ToM tasks (Shamay-Tsoory, Tomer, Yaniv & Aharon- Peretz, 2002). Separating the mentalising process was first proposed by Brothers and Ring (1992), who suggested that it may be more appropriate to define it as 'hot' and 'cold' theory of mind abilities, where 'hot' ToM would refer to emotional inferences made whilst the 'cold' reflected the cognitive aspects of ToM. This proposal is often linked with the more recent postulation by Shamay- Tsoory et al., 2002 (Shamay- Tsoory, Tomer, Berger & Peretz, 2005; Shamay- Tsoory & Aharon-Peretz, 2007a; Shamay-Tsoory, Aharon-Peretz & Levkovitz, 2007b). These authors outline that the theory of mind can be subdivided into cognitive and affective components as seen in the concept of empathy (Kramer, Mohammadi, Donamayor, Samii & Munte, 2010). Cognitive theory of mind considers inferences regarding other people's beliefs while affective theory of mind refers to the inferences made regarding others' emotions (Shamay-Tsoory et al., 2007).

Another manner in which mentalising has been compartmentalised is depicted by (Tager-Flusberg & Sullivan, 2000). They recommend that theory of mind be considered has having one component responsible for detecting or decoding mental states from the available observable information, this includes facial expressions, biological motion and action understanding. While the second component considers the reason behind the mental state in order to explain or predict the individuals' actions. This can be referred to as making a distinction between the social perceptive component of theory of mind and the social cognitive component.

Theory of mind within the current instance will be considered in terms of the more general and basic definition, in the sense that the task used shall not consider the idea of splitting theory of mind abilities into either cognitive/ affective ToM or social perceptive/ social cognitive components of ToM.

The debate surrounding how our mentalising skill should be defined is not the only disputable issue within the ToM literature. As controversy revolves around how we integrate the vast amount of information required for our ToM aptitude. Currently there are two key theories which have attempted to explain the method behind this aptitude. One hypothesis is known as 'Theory Theory' it argues that the mental states attributed to other people are conceived from unobservable, theoretical posits, invoked to explain and predict behaviour (Gallase, Keyers & Rizzzolatti, 2004). Therefore we have principles and concepts which govern the inferences we make about others (Apperly, 2008). Whilst the alternative process known as the 'Simulation Theory' explains how mental states of others are presented by tracking or matching their states with meaningful states of one's own (Gallase et al. 2004). This theory allows for one to model other's intentions and future actions using our own mind. This capability could be facilitated by the mirror neurones (Pineda, 2009), as these are known to discharge not only for our own specific actions e.g. moving our foot but also when witnessing others foot movements for example. (Gallase et al., 2004). Therefore the perceived behaviour of another could be matched to one's own behaviour and the most common goals associated with it.

Although seemingly opposite theories neither of them should be considered as mutually exclusive (Carrington et al., 2009). As the simulation theory could support the development of theory of mind and the representation of simple mental states, whilst the more complex aspects of mental states require additional cognitive processes which are conducted by the 'theory theory' process (Mitchell, Banaji, Macrae, 2005; 2006) Alternatively one theory i.e. 'theory theory' can be activated when the other i.e. the simulation theory is inappropriate or unavailable (Carrington et al., 2009). Or if one considers the idea of mentalising as two aspects perhaps one theory controls one component whilst the other is controlled by the remaining theory e.g. 'theory theory' drives our cognitive ability whilst affective theory of mind could be linked with the 'Simulation Theory.'

Developmental studies often refer to the progression of our theory of mind aptitude in terms of which mentalising task we can competently complete. Therefore between the ages of 3 and 4 years old the child is considered to understand first order false belief tasks, meaning that they are capable of understanding that people may hold false beliefs (Mitchell & Lacohee, 1991; Wimmer, 1983; Baron-Cohen, Leslie & Frith, 1985). At this stage they have a limited repertoire of mental concepts, such as desires and perceptions (Saxe, Xiao, Kovacs, Pervet & Kanwisher, 2004). As the child matures their theory of mind ability becomes more

sophisticated, by the age of 6 and 7 years old they able to complete second order false belief tasks and hence understand a belief about a belief (Wimmer & Perner, 1985). At this age there is a significant increase in the use of personality traits and they appreciate that how people have particular personalities which will help to predict their future actions and behaviours (Wellman, Cross & Watson, 2001). At the age of nine years old a child should have developed complex social skills which can be illustrated by faux pas tasks (Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997), these tasks concern the child realising that the listener might not what to hear or may hurt by what is said within the story they are asked to read aloud (Stone, Baron-Cohen & Knight, 1998). At adolescence they have the ability to recognise emotions and mental states.

There are clearly different levels of difficulty within our ToM ability ranging from our simple first-order ToM tasks to more complex faux pas tasks, between which there is of course the intermediate level known as second-order ToM tasks. The ability to complete these different task levels obviously develops over time. Not only can the level of our ToM ability be measured but our ToM ability in general is often measured by a range of different assessment tools. These can come in the forms of simple word lists (Baron-Cohen & Goodhart, 1994), stories (Happe, 1994), cartoon strips (Gallagher, Happe, Brunswick, Flether, Frith & Frith, 2000), photographs (Baron-Cohen, Ring, Wheelwright, Bullmore, Brammer, Simmons & Williams, 1999) or indeed a combination of previously mentioned. The extent of experimental paradigms utilised to investigate ToM shall be discussed later in this section when considering which of the ToM tasks have been used within brain imaging literature. However, concentration at present turns to the task that shall be used within this research to measure ToM capabilities. The task which shall be administered within this paper was first developed by Baron-Cohen, Campbell, Karmiloff-Smith, Grant, and Walker (1995). To the best of the researchers knowledge this is the first time that this task will be administered within an fMRI study. The task monopolises eye gaze detection as within various development studies eye gaze is often referred to as a central precursor to our ToM ability (Baron- Cohen., 1995; Wicker, Michel, Henaff, Decety, 1998) These studies show how the building blocks of direct and mutual eye gaze lead to joint and shared attention processes which underpin our theory of mind ability, as quite often eye gaze is used to direct our attention to and from others and our own objects of (Baron-Cohen, Campbell, Karmiloff-Smith, Grant & Walker, 1995; Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997; Emery, 2000).

With this evidence Baron-Cohen et al., (1995) developed an eye gaze preference task which would assess our mentalising ability, whilst minimising our executive functions. Endeavoured to this as it was felt that some ToM tasks not only rely on our ToM process but also involve our executive functioning processes. The concept behind the task is that the participant shall make judgements on another's mental state from their eye gaze. However, this eye gaze preference task requires the development of different conditions, where one condition considers the individuals ToM ability whilst the other acts as the control condition, which the ToM condition can be compared against. The general task often consists of four pictures being placed on a screen, each picture belongs to a particular category (e.g. fruits) and each picture is positioned in one of the four corners. In the middle of the screen a cartoon face is displayed and at the top of the screen a sentence appears asking the participant to pick one of the pictures. The picture which the participant chooses depends on which condition the subject is within.

Although developed by Baron-Cohen et al., in 1995 the task has been adapted recently in several papers. As Snowden, Gibbons, Blackshaw, Doublebay, Thompson, Crauford, Foster, Happe & Neary (2003) used a paper version of the task comparing a ToM condition task which contained a distracter arrow to a control condition. The ToM condition in this paper contained four pictures one in each corner and a face in the middle, the faces eyes were directed towards one of the four pictures and the face would be expressing a happy emotion e.g. smiling. The participant was asked which picture the face likes best? As well as this an arrow would be present on the screen pointing to one of the pictures that the face was not looking at, potentially distracting the participants. This display was then compared to their control condition which was identical to the ToM condition task except that the face expressed no emotion and the arrow had been removed. The participants within this study were also asked which picture was their favourite and assessed in terms of their ability to detect eye gaze direction.

The eye gaze preference task has also been used within a variety of studies conducted by Shamay-Tsoory and colleagues (2005; 2007; 2007) however, within these studies the eye gaze task is often broken into affective and cognitive ToM tasks as well as first and second order ToM tasks. Within these studies the participant has be infer emotional inferences using eye gaze aka affective ToM and non-emotional inferences e.g. which picture is the face thinking of from eye gaze cues (cognitive ToM). Again as seen in Snowden et al., this study

develops several different ToM conditions and compares these against control conditions e.g. a physical task in which the participant has to purely judge the direction of the eye gaze or which picture the face is closest too. Within both these studies accuracy scores were recorded in terms of whether the individual picked the correct picture for each condition and also error types were considered as it was noted within Snowden et al. (2003), study that FTD patients frequently made the mistake of choosing their personal favourite picture.

A variation of this eye gaze task shall be constructed to be administered within this paper. Like the previous studies monopolising this task there will be three different conditions: a Favourite condition, a ToM condition and finally a Control condition. The favourite condition will assess the subjects' personal favourite picture. Whilst the ToM task infers which picture the face likes best by simply using eye gaze direction and a facial expression of happiness. The control condition shall then simple assess the individuals' ability to detect eye gaze direction, with the face showing no emotional expression. Unlike other ToM tasks this ToM eye gaze preference task is less structured and so more open-ended responses will be acquired. As in Snowden et al.(2003) and the various Shamay-Tsoory studies (2005; 2007; 2007) the subject will be assessed in terms of the accuracy in answering and their error types displayed. The ToM task within this research shall consider the first-order level ability of ToM processes.

Mentalising is clearly one of the aptitudes that governs' our social interactions within the social world and one which appears to be conducted effortlessly. However, there are some disorders i.e. autism (Baron-Cohen et al., 1985; Happe et al., 1994), schizophrenia (Brunet, Sarfati, Hardy-Bayle, & Decety, 2000; 2003; Brune, Lissek, Fuchs, Wittaus, Peters, Nicolas et al., 2008), behavioural variant of Frontotemporal Dementia (bvFTD) (Lough, Kipps, Treise, Watson, Blair & Hodges, 2006; Snowden et al., 2003) and variants of Motor Neurone Disease (MND) (Goldstein & Leigh, 1999; Girandi, Mac Pherson & Abrahams, 2010), which postulate that the individuals with these disorders have impairments within their ToM ability. Within all of these disorders the individual often suffers from social and behavioural alterations, it has been suggested by the numerous researchers these problems can be sourced to impairments within ToM skills. Autistic individuals' deficits of ToM are noted within their lack of social interactions, their social inappropriateness, communication deficits and restricted interests (Baron-Cohen et al., 1985; Happe et al., 1996). Whilst clinical symptoms such as loss of volition, inertia, disinhibition and distractibility, impulsivity and perseveration

have been noted in patients with bvFTD and MND (Neary, Snowden, Gustafson, Passant, Stuss, Black, 1998; Goldstein et al, 1999; Girandi et al., 2010). Patients with these diseases often suffer a breakdown in their social relationships and must often have no appreciation of their own illness and symptoms. Schizophrenia patients' inability to mentalise is highlighted through their misinterpretation of social situations as they cannot perceive social and emotional cues (Morrison, Ohman & Dolan, 1998; Bell, Lysaker, Bryson & Kaplan, 1997).

1.3 Neural Correlates of Social Cognition.

As previously emphasised from the reviewed literature it appears that social cognition and the process of theory of mind is crucial for our social existence and without it or the appropriate level of support one can become unintentionally socially withdrawn from the rest of the world. Due to its importance it has often been suggested that our social cognition is controlled by a specific set of brain regions. Evidence for this is seen in the existence of individuals who appear to have no problem with the non-social world e.g. they are capable of difficult problem solving but find the social world confusing and foreign (Baron-Cohen, Wheelwright, Stone & Rutherford, 1999). It then appears that the opposite of these individuals exist, where individuals have no problems within their social realm but instead their deficit lies within the non-social world perhaps within problem solving (Karmiloff-Smith, Grant, Bellugi & Baron-Cohen, 1995; Damasio, Tranel & Damasio, 1990). This presents researchers with a functional double dissociation, as it appears that social cognition deficits can exist independently of non-social cognitive abilities and vice versa. Authors have therefore contemplated that this double dissociation could be possible due to the hypothesis that our social and non-social cognitive abilities are controlled by two separate brain circuits. This particular study is interested in which areas have been highlighted for our social cognition aptitudes.

Brothers (1990) propose the idea of a social brain from primate research using single neurone recordings. This investigation led to various cortical regions being implicated in the social brain such as the amygdala (AMY), orbitofrontal cortex (OFC) and superior temporal gyrus (STG). Each of these structures was proposed to be responsible for specific social cognition processes, the amygdala was activated during emotional judgements, the OFC considers social appropriateness and finally the STG perceives faces. Brothers (1990) also

made reference to the inferotemporal cortical regions, including the temporal pole and the cingulate gyrus.

In addition to the cortical regions mentioned above there are further regions advocated for our social cognition. These include the idea that the extra-striate body area governs our visual perception of bodies as stated in a review of fMRI studies considering the areas which have been noted to respond selectively to images of the human body (Downing, Jiang, Shuman & Kanwisher, 2001). The superior temporal sulci (STS) was found to be activated for the analysis of biological motion cues, which can then be used for the interpretation and prediction of others social intentions investigated via a PET study which compared hand and body motions versus object and random motions (Bonda, Petrides, Ostryi & Evans, 1996). The fusiform gyrus (FFG) responds during face perception and recognition as illustrated in an fMRI which presented faces versus common objects (Kanwisher, Mc Dermott & Chun, 1997). Whilst the medial prefrontal cortex (mPFC) is important for reasoning about the beliefs of other individuals and perhaps a wide variety of social cognitive process regarding intentions and mental states, (Castelli, Frith, Happe, Frith, & Frith, 2000). Morris, Frith, Perret, Rowland, Young, Calder et al., (1996) suggest that the amygdala recognises the emotional states of others as it was activated during an fMRI study in which they presented photographs of fearful and happy expressions, but it is also known to be highly interconnected with the cortical and subcortical areas of the brain. While the temporal parietal junction (TPJ) could important for attributing beliefs to others and reasoning about those beliefs, as Saxe and Kinwisher (2003) found activations within this regions when administering a story paradigm ToM task within an MRI scanner. The precuneus and the posterior cingulate have been identified with self knowledge as within a PET study these areas were highlighted for the task that reflected one's own personal traits, when compared to tasks that required reflections on another's' personality or those that reflected social issues (D'Argembeu, Collette, Van der Linden, Laureys, Del Fiore, Degueldre, Luxen & Salmon, 2005).

1.4 Neural Correlates of Theory of Mind

The is an overwhelming amount of research to suggest that there is neural basis for social cognition but the current research concentrates on the idea that there are particular neural regions which mediate our mentalising skill. The notion that theory of mind has its own neural basis has been widely speculated and often researchers debate over the hypothesis

that there is one particular brain region regulating this aptitude or that the process is underpinned by multiple brain areas.

The enquiries made thus far into this suspicion have monopolised a range of methods from clinical/ lesion studies to brain imaging papers or a combination of both. Papers addressing this issue via clinical populations such as schizophrenia patients have used brain imaging techniques whilst administering ToM tasks to highlight abnormalities within the superior temporal lobe and temporo-parietal junction (Bebedetti, Bernasconi, Bosia, Cavallaro, Dallaspezia, Falini, et al., 2009), orbitofrontal/ ventromedial prefrontal region (Brune et al, 2008; Gold, Goldberg & Weinberg, 1992) and the left inferior frontal gyrus extending into the insula (Russell, Rubia, Bullmore, Soni, Suckling, Brammer, Simmon, William, Sharma, 2000). All of these areas have therefore been speculated as where the theory of mind disabilities originate from.

Pathological changes within patients with the behavioural variant of FTD have been noted within the frontal lobe but as the disease progressives the brain abnormalities spread to some sub-cortical structures for example the parietal and temporal cortices (Neary, Snowden, Shields, Burjan, Northen, Macdermott, et al., 1997; Snowden et al., 2003). Often the predominant area of deterioration lies within the frontal lobe and is known as ventromedial prefrontal cortex (Salmon, Garraux, Delbeuck, Collette, Zuandorf, Perani, et al., 2003). The autistic clinical population studies regarding this topic have been shown to have abnormalities within the superior temporal sulci, fusiform gyrus, the orbito prefrontal cortex, the amygdala and medial prefrontal cortex (Happe, Ehlers, Fletcher, Frith, Johansson, Gillerg et al., 1996). All of which have been speculated as areas for the theory of mind process. MND patients assessed using MRI imagery were seen to have alterations to their frontal and temporal cortices (Abrahams, Goldstein, Suckling, Ng, Simmons, Chitnis et al., 2005).

Lesions studies often correlate a particular lesion with a significantly inadequate ToM test result have highlighted some of the same regions referred to in the clinical populations. At times the clinical populations are often compared to particular lesion patients. Mentalising inabilities have been acquired after lesions within the frontal lobe (Rowe, Bullock & Polkey, Morris, 2001 ; Shamay- Tsoory, 2005) particular emphasised is the orbitofrontal cortex (Stuss, Gallup & Alexander, 2001; Shamay-Tsoory, Harari, Peretz & Levlovitz, 2009), medical prefrontal cortex (Stone et al, 1998) and the ventromedial area (Shamay-Tsoory et al., 2005). Samson, Apperly, Kathirgamanathan and Humphreys, 2005 report that following a

lesion within the left temporoparietal junction the patient experienced reasoning the beliefs of others.

The present research centres on using the advanced technology of brain imaging to consider our theory of mind ability. For this reason the review of the previous research concerning theory of mind and brain imaging shall now be considered, as this literature has utilised a vast range experimental paradigms to consider our mentalising ability.

One of the most dominant methods of assessing ToM is by assessing the participants' ability to recognise mental states. Baron-Cohen et al., (1994) using this recognising mental abilities concept the participants were presented with two lists of words, one referring to mental states whilst the other reflected body parts. Subjects would judge whether the words were consistent with the theme of the list. The mental state list acted as the theory of mind task whilst the body part list reflected the control task. Using SPECT technology increased activations were found within the orbitofrontal cortex and the medial prefrontal cortex for the mental state list. Baron- Cohen et al., 1999 extended this investigation using whole brain analyses and a different task which involved judging various mental states from a range of photographs which captured the eye region. Results found that activations for this were found within the medial prefrontal cortex (mPFC), left prefrontal cortex, SMA, anterior cingulate cortex (ACC) , superior temporal sulci (STS)/superior temporal gyrus (STG), MTP, temporal parietal junction, amygdala and insula.

An alternative method considering recognition of mental states was used by Mason, Banfield and Mancrae (2004) this involved using target words and pairing them with subsequent action words, the participant had to decide if the action word could be used to describe the target. The target words were either human or dog. The hypothesis here was that our theory of mind ability would be triggered only when action words were associated with humans, as this would automatically evoke attributions of mental states. Activations related to this task were found in the middle and medial frontal gyri, the right anterior cingulated cortex, the SMA, mPFC and the ACC. Mitchell et al., (2005) adapted this technique using a target- adjective pairing task, but results indicated activations in the right dorsomedial prefrontal cortex for our mentalising skill.

Simple questions considering mental states are an alternative mode of investigating ToM (Ganis, Kosslyn, Stose, Thompson & Yurgelun, 2003; Kozel, Revell, Lorberbaum, Shastri, Elhai, Horner et al., 2004; Spence, Farrow, Herford, Wilkinson, Zheng & Woodruff,

2001). Within these studies the individuals would often be asked to distinguish between truth and lies or exhibit lies and truths themselves whilst imaging took place. These various studies have found activation within the medial/orbital prefrontal cortex (Ganis et al., 2009; Kozel et al., 2004; Spence et al., 2001), lateral prefrontal regions (Spence et al., 2001), the cingulate cortex (Kozel et al., 2004; Spence et al., 2001) and the fusiform gyrus (Ganis et al., 2003).

A substantial amount of theory of mind literature has employed stories as a means of understanding how people attribute mental states, these tasks require the participant to infer various beliefs/intentions/desires from fictional characters. Happe (1994) composed three categories of stories investigating theory of mind, these stories were later adapted by Fletcher, Happe, Frith, Baker, Dolan, Frackowiak and Frith (1995). These three categories involved a ToM story, a physical causality story and finally one which contained unlinked sentences. Within these investigations the critical comparison is between the ToM and the physical causality story. Using PET Fletcher et al., 1995 found activations within the left mPFC, the ACC, the posterior cingulate cortex (PCC) and the right IPL with only the left MFG responding exclusively to the theory of mind condition. Gallagher et al., (2000) and Gobbini, Koralek, Bryan, Montgomery and Haxby (2007) using a simpler technique found activations within the medial prefrontal cortex, temporal poles and temporoparietal cortex. However, Gobbini et al., (2007) found additional responses within the anterior and posterior regions of the cingulate gyrus.

Vogeley, Bussfeld, Newen, Herrmann, Happe, Falkai et al. in 2001 using the original stories designed by Happe (1994) found activations within more posterior areas, in ACC. This study additional considered the neural responses elicited when the subject placed themselves within a story. This paper questioned if the neural responses for this condition would differ from that of our theory of mind. Activations for this particular condition were found within the ACC, the right TPJ and the medial regions of the superior parietal lobe. Vogeley concluded that this meant the ACC vital in contributing to our theory of mind ability and that different brain regions would be linked with how we assign mental states to ourselves.

Saxe et al., (2003) extended the story technique to include four conditions reflecting false belief, human action, non-human inferences and mechanical inferences. The theory was that the first two conditions represented mentalising and results indicated that these two tasks provoked activations in the anterior STS and the TPJ. In a later study analysing whole brain

activity and comparing false belief stories and false photographs were found to activate the right medial superior frontal gyrus and the frontal pole (Saxe et al., 2003). This study provided further sustenance an earlier ERP study by Sabbagh and Taylor (2000) which implicated the left frontal lobe as a site of theory of mind abilities.

Thus far the tasks assessing theory of mind have involved different verbal capabilities however there are papers analysing mentalising through a non-verbal means. For instance static images have been manipulated to reflect theory of mind abilities within various brain imaging techniques. Some of the static images reflect the same basic idea as seen for the story studies, hence they involve a theory of mind image, a physical causality image and an image one made up of jumbled pictures. With this task neural responses were seen in the medical prefrontal cortex (mPFC) bilaterally, the right precuneus and fusiform gyrus (FFG) (Gallagher et al., 2000). Further non-verbal tests can be seen in the form of the well known Sally-Ann format, in which one cartoon depicts a change in location of an object, the change is made either with (true belief) or without (false belief) the critical protagonists awareness (Sommer, Dohnel, Sodian, Meinhardt, Thoermer & Hajak, 2007). These false belief cartoons have evoked heightened activity in several regions, the dorsal ACC, the PFC and the right TPJ (Sommer et al., 2007). Authors have suggested that the ACC and the PFC had non-roles and that the only region of importance was the TPJ which is specific for ToM abilities. Lissek, Peters, Fuchs, Wittaus, Nicholas, Tegenthoff et al. (2008) considered ToM in the same manner and evoked neural activity in the superior, inferior and medial regions of the PFC, the ACC (anterior cingulate cortex), the temporal parietal junction, precuneus and insula.

Comic strips depicting theory of mind paradigms have been used in a number of studies (Brunet et al., 2000; Ciaramidaro, Adenzato, Enrici, Erk, Pia, Bara et al., 2007; Vollm, Taylor, Richardson, Corcoran, Stirling, McKie, Deakin & Elliot, 2006; Walter, Adenzato, Ciaramido, Enrici, Pia & Bara, 2004). These paradigms typically highlighted areas in the medial and inferior areas of the right PFC including the ACC, anterior temporal regions bilaterally and the left cerebellum when the theory of mind condition was compared to the physical causality condition (Brunet et al., 2000). Vollm et al. 2006 conducted research with this particular task showing activations in the medial prefrontal and orbitofrontal regions, the TPJ and the temporal cortex.

Walter et al., (2004) using a similar cartoon format to Vollm et al., (2006) but with the addition of another character, the additional character meant the participants had to distinguish between the private intentions of one character and private intentions of two characters and communicative intentions. This study as well as noting the typical areas within the PFC also implicated the PCC (paracingulate cortex) as being engaged in the processing of mental states, specifically when these intentions were associated with social interactions. Ciaramidaro et al., investigating the same idea of private intentions and possible social intentions also demonstrated activations within the anterior paracingulate.

There are a few studies that have considered the idea that there could be differences between the evoked activations found in theory of mind story tasks and cartoon tasks. Gallagher et al., (2000) found that independent of these modalities, theory of mind tasks activated the medial prefrontal cortex bilaterally. However, Kobyashi, Glover and Temple (2007) failed to replicate this finding, although within this study there were a number of adjustments to how the stimuli were presented to the subjects. This study noted how there appeared to be a more activation in the left STG and the right MTG for the story tasks. While modality- independent activation was found in dorsolateral prefrontal cortex as well as more posterior regions which included the right IPL and bilateral TPJ. Further analysis using the technique of region of interest analysis implicated the TPJ bilaterally and the right IPL as specific for theory of mind compared with both modalities. The two groups concluded that there are regions in the brain which are associated with mentalising regardless of verbal task demands that the mPFC and the TPJ. Kobayashi, et al (2007) also examined age within their study with results finding both age groups showed significant activity in the TPJ bilaterally and right inferior parietal lobule (IPL) in a modality independent manner.

Photographs are an alternative method of non-verbal tasks used to research theory of mind brain activations. One typical way in which photographs have been used involves presenting the photograph and asking the participant to simply make judgments of whether the face is happy or not, this neural activate was then compared to neural responses evoked when asked to judge if face in the photograph is symmetrical. Activations for these studies have been found in the dorsomedial prefrontal cortex, the TPJ in the STS and the left amygdala (Mitchell et al., 2005). An additional condition was added debating if the face was similar to the subjects face, results show a negative correlation found between the dorsomedial PFC and the a positive correlation between in the ventromedial PFC (Mitchell et

al., 2005). Mosconi, Mack, Mc Carthy and Pelphrey (2005) combined animations and videos to consider the concept of theory of mind, finding increased activation in the posterior STS, the middle temporal gyrus and the IPL of the right hemisphere. This was one study that did not activate the medial prefrontal cortex. Goel, Grafman, Sadato and Hallett (1995) researching theory of mind evoked excitation for ToM within the orbitofrontal region.

Calarge, Andreson and O'Leary (2003) using PET and a paradigm concerned to be more ecologically valid than previous research as it involved the participants inventing and placing themselves within various imagery encounters with strangers. This study produced neural responses within the left medial, superior and inferior frontal regions, the anterior, para and retrocingulate which extended bilaterally, the angular gyrus, temporal pole and the right cerebellum. Gallagher, Jack, Roepstorff and Frith (2002) using a computer game task to assess theory of mind capabilities found activation within the frontal region and the paracingulate.

The majority of the studies mentioned have considered the idea of theory of mind using either false belief (first order or second order) or faux pas test. However, there are investigations which use the mental state of deception to investigate theory of mind, as deception does require the subject to consider others beliefs in the same way a false belief task might. Plus the act of deceiving another person involves the intentional manipulation of those beliefs. Activations for deception studies have been found in the frontal cortex which includes the orbitofrontal cortex and frontal gyrus, in the anterior cingulate and in superior temporal and cerebellar regions (Kozel et al., 2004).

Just as deception is considered to assess theory of mind so too does the idea of intentions and empathy. Authors that have considered the idea of intentions are Brunet et al., 2000; Ciaramidaro et al., 2007; Iacoboni, Molnar-Szakacs, Gallase, Buccino, Mazziotta and Rizzolatti, 2005; Mosconi et al., 2005; Vollm et al., 2006; Walter et al., 2004) these various studies have illuminated the mPFC, the ACC, and the superior temporal regions as involved in theory of mind. Vollm et al., (2006) considered which areas of activity overlapped for empathy and theory of mind tasks, overlap illustrated in the medial prefrontal, orbitofrontal regions, the TPJ and the middle and inferior temporal regions. When separately considered intentions saw greater response within more lateral frontal cortex and in more superior temporal regions.

Carrington and Bailey (2009) in a review of neuroimaging literature noted how out of 40 studies 35 paper noted activation with the medial prefrontal cortex, 35% of the studies included the LPFC as an area involved in theory of mind. Eight out the forty papers mentioned the SMA while 5 papers referenced the orbitofrontal cortex. The motor cortex responded in one study considering ToM, the ACC was found to be activated in 15 out of 40 papers. 25% of the research reviewed included the paracingulate as relevant to out ToM ability. The precuneus was noted to produce neural excitation in 28% of the paper, whilst 15% of the papers reported PCC and IPL activations (not necessarily the same papers). Ten out of forty papers elicited activation in the temporal poles and the cerebellum, whilst 45% noted how the STS/STG and TPJ were associated with mentalising. A further 20 % found neural responses in the MTG, occipital lobe and fusiform gyrus. While 5 papers found activation in the amygdala and 5 found activation in the Insula.

It is clear from the brain imaging literature that a variety of tests have been used to investigate the neural correlates of theory of mind. It is not surprising then that from these studies a number of areas have been referenced as important for our mentalising aptitude. Of course the variations of brain regions mentioned could be due to the various experimental paradigms. But the variation has also been linked with whether the individual has been explicitly told to consider the other individuals mental state. As although generally assumed that theory of mind is an automatic process there are studies which have suggested otherwise (Apperly , Riggs, Simpson, Chiavarino & Samson, 2006). The variety as also been blamed on the diverse number of mental states that have been studied e.g. false belief, deception and intentions. As even within false belief studies there has been different neural responses elicited for first and second false belief tasks.

From the literature considered it appears that our ToM aptitude could be sub-served by a variety of brain regions. However, there are often areas which researchers pinpoint as being the core region for ToM. One of these regions is the PFC in particular the mPFC/ OFC regions (Brunet, Sarfati, Hardy-Bayle and Decety, 2000; Fletcher et al., 1995; Gallagher et al., 2000; Happe et al., 1996; Vogeley et al., 2001; Gallagher et al., 2002; Goel et al., 1995) and only four studies thus far have failed to activate this area when considering ToM. Theorists suggest that since the PFC is a large area of the brain and since it has a series of intimate connections with other brain areas (the anterior insula, temporal pole, inferior parietal region and the amygdala), these two characteristic allow for it to in a position to

evaluate and regulate incoming information which can consequently be used to inhibit behaviour, regular emotions and empathise with the experiences of others. Therefore this area could be the most appropriate for the integration of the vast amounts of social information required for our mentalising capability. A further hypothesis is that this large area could be split into different abilities regarding our theory of mind ability. As perhaps the right orbitofrontal medial temporal circuit involved in processing others mental states on immediate information and the left medial frontal circuit is involved in more complex reasoning.

However, evidence from a lesion study noted how even when an individual who sustained profound damage to their prefrontal cortex was still able to complete theory of mind tasks (Bird, Castelli, Malik, Frith & Husain, 2001). Due to these studies a shadow of doubt has cast on the mPFC/OFC ability to conduct our ToM processes. Some theorists have alternatively suggested that the core area for our theory of mind capabilities is the TPJ (Saxe et al., 2003; Saxe and Wexler, 2005). Stating how this area is where reasoning about others beliefs takes place. It appears that this region is also involved in non-social tasks that require participants to redirect attention to task-relevant stimuli. (Saxe et al, 2003).

But the fact remains that a variety of studies have also found activation within more peripheral areas, such as the amygdala, STS and the anterior and para-cingulate cortex. Gallagher and Frith (2003) reviewed mentalising brain imaging research and suggested that the mPFC, temporal poles and the STS are involved in the processes required for mentalising. Stating that perhaps the mPFC is more vital for this ability whilst the STS and temporal poles are less uniquely involved in the process.

It seems unlikely that one region alone accounts for our ability to mentalise, instead it may be more adequate to theorise that these is a neural circuit within the social brain governing our ToM capacity. Therefore perhaps a variety of the brain regions mentioned are indeed involved such as the mPFC, TPJ, STS/STG and the temporal poles to allow us to competently complete all aspects of mentalising. Perhaps there is even some interconnected regions underlying our theory of mind, as evidence suggests that some white matter lesions have lead to a disturbance with our theory of mind (Bach, Davis, Calvin, Wijerante, Happe, Howard et al., 1998; Happe, Malhi & Checkley, 2001).

1.5 Present Study

The main aim of this study is to pilot the eye gaze preference task within an fMRI environment, to ensure that this task can used within future brain imaging research. As well as this the study hopes to speculate on which areas of the brain are relate to our ToM ability when using a simple eye gaze preference task.

In order for the eye gaze preference task to run efficiently within an fMRI study the task has to have certain time restrictions for when and how long the subject has to respond with their answer. To ensure that it was possible for participants to answer within these time constraints a pilot study shall be performed using the identical time restraints that are set out by an fMRI study. Therefore the pilot study's main aim will be to ensure that the participant can appropriately answer within these time restraints. This study shall be analysed and found successful if the participants are able to respond to each of the tasks and accuracy levels for all conditions are high. It is predicted that the controls will have no problems with assessing which picture the face likes best, nor should there be any deficits with detecting the eye gaze direction, as all participants within this study shall be 'healthy' controls with normal ToM capabilities. If any errors do occur they shall be classified as seen in Snowden et al., 2003 as either favourite errors or unclassified errors.

If completed adequately the task shall be administered within an MRI scanner. Within the fMRI study the objective is to ensure that the task is eliciting brain activations that differ to that of the baseline, therefore the task can be used as a ToM task within further fMRI studies. This study is also interested in whether there are any differences in the neural activations elicited during the ToM task when compared to the control condition and the favourite condition. Just as in the pilot study the participants within this study are considered to be healthy controls therefore none of the subjects should have difficulties with any of the task conditions, in fact accuracy scores should be almost perfect. When comparing the neural emissions for each task condition against each other it is hoped that one would find increased BOLD activations for the ToM condition within the mPFC/ OFC and TPJ as these two regions mentioned as two crucial areas within ToM literature (Gallagher et al., 2000; Saxe et al., 2003). There may also be some activations in the amygdala due to the emotion expressed on the face (Morris et al., 1996) and perhaps activations within the STS/STG as these areas are associated with detection of eye gaze direction (Itier & Batty, 2009).

2. Method

2.1 Experiment One: Pilot study: Off line

2.1.1 Participants.

Eight healthy individuals, 7 females and 1 male were asked to take part in this experiment. Their ages ranged from 23 years old to 60 years old, with an average of 40.5 years old. Before commencing the experiment the participants were deemed 'healthy' through questions concerning their medical history and assessing their IQ via the Wechsler Test of Adult Reading neurological assessment (WTAR; Weschler 2001) this prevented any conflicting results obtained due to medication, medical conditions or intellectual ability. The four older subjects were randomly selected from a volunteer panel supplied by the University of Edinburgh, whilst the younger participants were all students who attended the University of Edinburgh. All subjects received information concerning the research via interactions with the researcher and information sheets. Each participant gave formal written consent to partake in the study.

2.1.2 Stimuli

Information sheets, consent forms (see appendix 1) and three separate recording sheets were constructed for each task condition (Favourite, theory of mind and control condition (see appendix 2, 3 and 4)).

As mentioned in the introduction the task developed for this experiment was originally constructed as a paper version by Baron-Cohen et al., (1995). The concept behind the task is that the participant is required to make preference judgements based on eye gaze cues. Unlike the original task this paper constructed a computerised version of the eye gaze task within E-Prime (E-Prime, 2000). As set out in the introduction the task will have three different conditions: the Favourite condition, ToM condition and the Control condition. The favourite condition in this experiment is considered to be a pre-experimental condition as its purpose is to assess the individuals' personal favourite picture, controlling for errors that could occur in the experimental conditions due to the individual simply picking their favourite. The ToM and Control condition are referred to as the experimental conditions. The ToM condition allowed the researcher to assess the participants' ability to infer the mental state of another using an eye gaze cue. The control condition assessed the subjects' ability to detect eye gaze direction, these two conditions were then assessed within the results.

Each of the task conditions consisted of 10 blocks with 5 trials per block. Each condition ran consecutively, with the favourite condition running first followed by the ToM condition and finally the Control condition. Each of the subjects was presented with the task conditions in the same sequence as previously mentioned. The trials in each condition were separated with fixation crosses which appeared on the screen for 500 milliseconds. The experimental conditions' (ToM and the control condition) blocks were interspersed with 17 second rest periods. For each of the task conditions the participants would say which of the pictures they were choosing.

The task for each of the conditions consisted of presenting the participant with a screen, on which there is four pictures belonging to the same category (fruits, animals, vegetables, household items and cartoons), the pictures were positioned in one of four corners of the computer screen (upper left, upper right, bottom left and bottom right). For the pre-experimental favourite condition, a text box at the top of the screen read "Which picture is your favourite." An example of the stimuli used in this condition can be found in figure 1. To move between the trials in this condition the participants simply pressed the space bar on the key board.

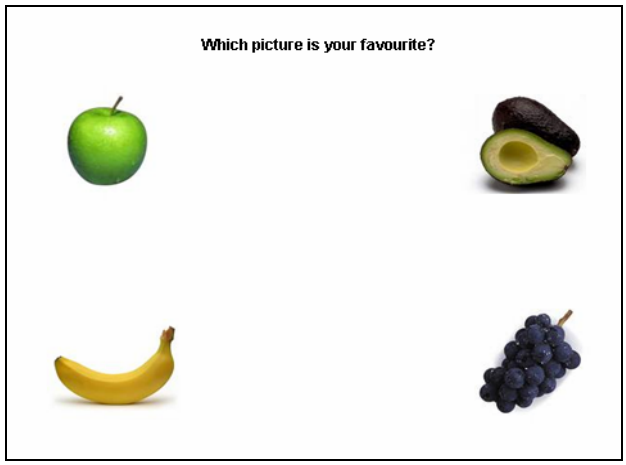

Figure 1: An example of the stimuli presented in the favourite condition for experiment one.

The experimental task conditions not only seen the four pictures presented but also displayed a face in the middle of the screen. Within the ToM condition the face would be expressing an emotion i.e. smiling, whilst in the control condition the face had no emotional expression. At the top of the screen in the ToM condition the sentence asked "Which picture

does the face like best?" and for the control condition the sentence said "Which picture is the face looking at?"

Although each condition required the participant to verbally respond with their answer the two experimental conditions stipulated that this was done at a specific time and within a time frame of four seconds. These time restraints were set as these matched the time constraints of the fMRI design which the eye gaze preference task would eventually be used within. To indicate when the subject should give their answers within the experimental conditions the face that was presented in the middle of the screen would change colour from yellow to green, staying green for four seconds.

To construct the ToM condition within E-prime a duplicate of the E-Prime programme for the favourite task was made. A smiling yellow face was then added to the middle of the screen for each of the trials. The faces were selected in a pseudo-random manner, so that the face would be looking at one of the four picture locations an equal number of times. To create the illusion that the face was changing from yellow to green, a copy of screen containing the yellow face was created and added to the E-Prime trial procedure. It was programmed to appear directly after the task screen that contained the yellow face. In the coped task screen the yellow faces were changed to their green counterpart. The task screen containing the yellow face was then programmed to show for 2.1 seconds whilst the task screen containing the green face was displayed for four seconds. An example of the ToM condition task can be seen in figures 2 and 3.

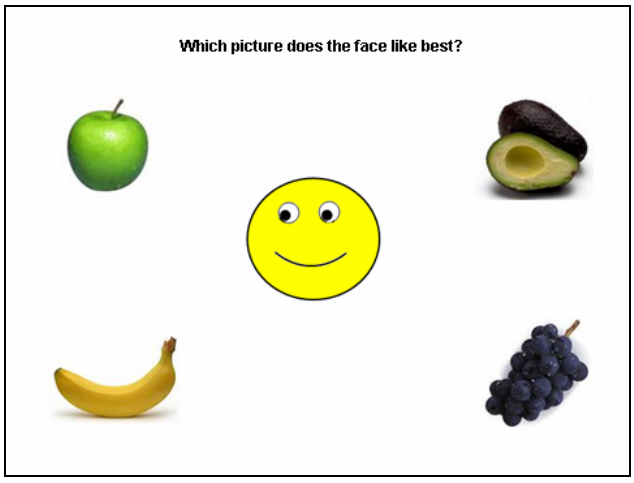

Figure 2: An example of the stimuli presented in the ToM condition, showing the yellow face which was programmed for 2.1 seconds.

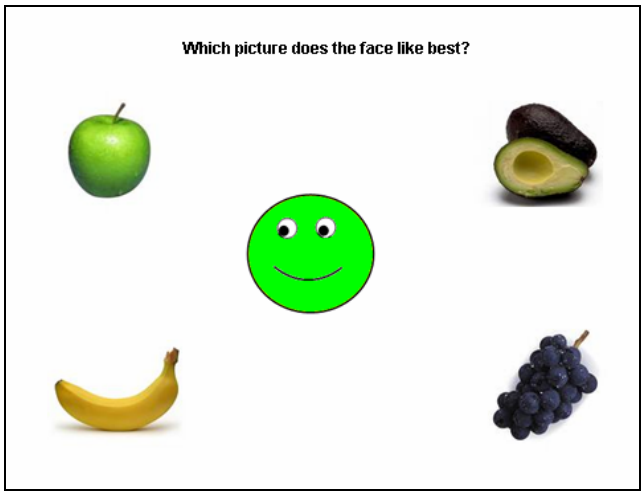

Figure 3: An example of the stimuli presented in ToM condition, showing the green face which was programmed for 4 seconds.

The task for the control condition was constructed by duplicating the E-Prime programme for the ToM condition, two small adjustments were then made after copying. One adjustment was made to the text box which now read "Which picture is the face looking at?" The second alteration was that the smiling faces were replaced by their neutral face counterparts. The task for the control condition is depicted in figure 4 and 5 below.

To construct the different task conditions various materials were required i.e. the faces and pictures which were presented within each of the tasks. The faces were created using Paint (Microsoft Office, 2007), each face was a simple circle which contained a set of eyes and a mouth, the eyes were made using two circles with black dots and the smiles were either curved or straight lines also created in Paint (Microsoft Office, 2007.) Four yellow faces were constructed displaying smiles and these four faces had their eyes looking at one of the four different locations. Duplicates of these four faces were then made but this time the face were green. A further four yellow faces were made displaying a neutral expression and each of the faces eyes were directed towards one of the four different locations. Duplicates were then made of these but instead of the faces being yellow they were green.

The pictures for the tasks were sourced through an internet search using basic five categories (fruits, vegetables, household items, cartoons and animals), totalling to 120 pictures. (See Appendix 5).

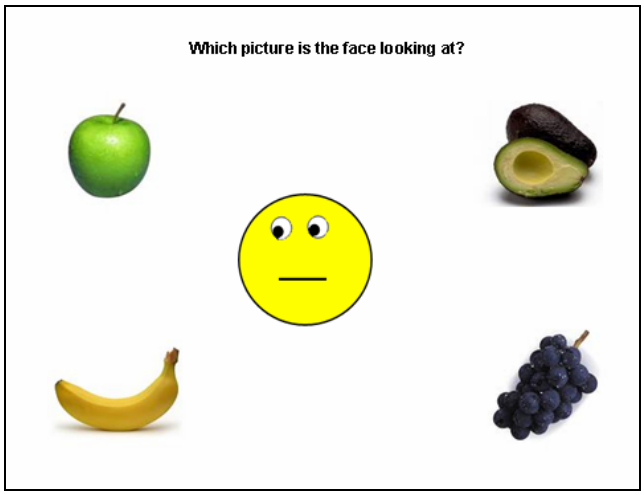

Figure 4: An example of the stimuli presented in the control condition, showing the yellow face.

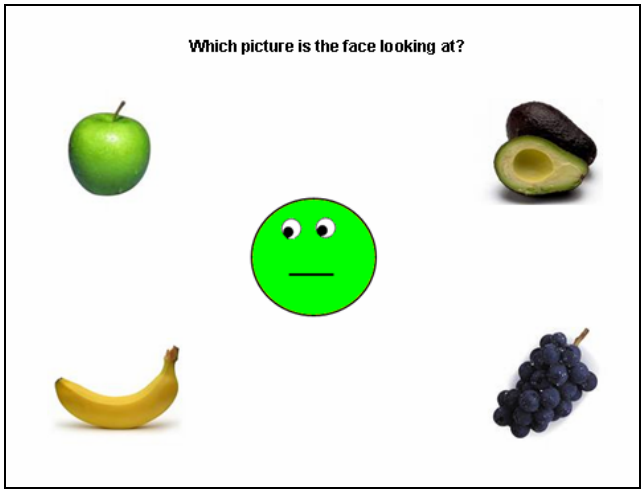

Figure 5: An example of the stimuli presented in the control condition, showing the green face.

2.1.3 General Procedure

Testing took place in the psychology building at the University of Edinburgh. On arrival the participants were greeted by the researcher and were given information sheets and consent forms to read and complete before testing commenced, this ensured that they fully understood the study. After formal consent was obtained the individuals were informally questioned concerning their medical history and administered the WTAR assessment (Weschler, 2001).

Subjects were then informed that the tasks were computer based and located on the laptop in front of them and that instructions for each task would be presented prior to the task beginning. The tasks for each condition were administered in the same sequence for each subject, starting with the favourite condition, followed by some practice trials for the ToM condition, then the 'real' ToM condition and finally the control condition task.

2.1.3.1 Favourite Condition procedure

The researcher informed the participant that this task condition involved naming each of the pictures that appeared on the screen and saying which picture was their favourite. Individuals were reminded that instructions would appear on the screen and they were informed to ask questions about the task through instructions. The instructions administered to participants for this condition can be located in appendix 6. After the instructions appeared the task procedure would follow.

2.1.3.2 Practice Procedure

Once the favourite condition was complete the participants were made aware that they were now going to complete a practice task for the second condition before performing the actual task. They were reminded to ask questions throughout the instructions as this task was now timed and asking throughout the task could be detrimental to their response. The researcher then commenced the practice task and participants were introduced to the face which would be seen throughout the next two conditions. The participants were informed that as well as viewing four pictures on screen, they would now see a face appearing in the middle of the screen. It was their task to infer which picture the face liked best. They were instructed to answer this question by verbally responding when the face in the middle turned green. They were asked to pay close attention as the task was timed and they would have to respond as quickly as possible when indicated. Subjects were asked to remain silent at all other times throughout the task except for when responding to give answer. Full instructions for this practice trial can be found in appendix 6. Once instructions were complete the task would commence and follow the E-Prime procedure of trials interspersed with fixation crosses as well having 17 second rest periods between each of the blocks.

If subjects responded whilst the face was still yellow they were reminded to wait until the face was green to say answer.

Once complete and if the researcher was satisfied with their performance on the task, they were informed that they would be starting the real task and that this would follow the same protocol and procedure as seen in the practice task.

2.1.3.3 Theory of Mind Condition Procedure

Full instructions for this task can be found in appendix 6. The task followed the same procedure as seen in the practice task.

2.1.3.4 Control Condition Procedure

Instructions for this condition were the same as those presented in the ToM condition, except that the subjects were asked to consider which picture the face was looking at. Full instructions for this task can be found in appendix 10. Task procedure for this condition is the same as outlined in practice ToM task.

2.1.4 Design

The task design for this experiment was a block paradigm. There were three conditions known as: Favourite condition, ToM condition and the Control condition. Each condition contained ten blocks with five trials in each block. Each condition ran consecutively, with the naming/favourite condition running first, followed by the 'like best' condition and finally running in full the 'looking at' condition. The experimental design is known as a within subject design as repeated measurements were taken from each participant.

2.1.5 Ethical Issues

Ethical approval was granted by both the NHS ethic committee and the University of Edinburgh's ethical committee. Each participant was informed that they could withdraw at any stage throughout the experiment and formal consent was obtained prior to taking part in research. They were given a full debriefing after the experiment was complete.

2.2 Results from Pilot study

This experiment was interested in the accuracy scores for the two experimental conditions and what type of errors were made through these task conditions. Displayed in Table 1 are the raw accuracy scores collected for each participant for the ToM condition and the control task condition, as well as the subjects' age. Table 2 illustrates the averages and standard deviations of the group concerning their age and total accuracy scores within the ToM task condition and the control condition. Analysis was conducted to assess if there was a significant difference between the accuracy scores for the ToM condition and the control condition. A non- parametric Mann- Whitney U test was conducted due to the small number

of participants and due to ceiling effects. Results indicated that there was no significant difference between the groups' mean accuracy score obtained in the theory of mind condition and the control condition, U= 28.00, $n_1=n_2=8$, P =0.721.

Table 1: Raw accuracy scores for each participant for both experimental conditions and the participants' ages.

Participants	1	2	3	4	5	6	7	8
Age (years)	50	58	60	52	23	25	27	24
ToM condition	50	50	48	50	50	50	50	50
Control condition	50	50	50	50	50	50	50	50

Table 2: Means and Standard Deviations for the group concerning age and accuracy scores for each of the experimental conditions.

	Age	ToM condition	Control condition
Mean (S.D)	45.87 (2.69)	49.75 (0.71)	50 (0.00)

As noted from Table 1 there was one individual who made two errors, neither of which were favourite errors therefore they were deemed unclassified errors.

The aim for this experiment was to ensure that the task could be run within a particular time restraints. These time restraints were set out to mimic the time constraints one would find within an fMRI study. It is evident from the results that this is indeed plausible, as the healthy controls were able to respond accurately for both task conditions within the time restraints stipulated. Therefore further investigations were constructed to implement the eye gaze preference task designed within this experiment into an MRI scanner, to obtain functional images of activations elicited during this particular task.

2.3 Experiment Two: fMRI study

2.3.1 Participants.

Six healthy individuals we asked to partake in this research, their ages ranged between 40 and 61 years old, with an average age of 51.8 years old. There were 4 females and 1 male.

Unfortunately one individuals' data was disregarded due to slight abnormalities found within the brain when scanned. The participants were recruited from a volunteer panel from the University of Edinburgh, with criteria simply being healthy 40-60 year old individuals. This age range was recruited as these subjects would form a control comparison group to patients with MND and FTD. Each participant was assessed and declared 'healthy' using a brief interview concerning their medical history, administering the WTAR neurological assessment (Weschler, 2001) and by completing the hospital anxiety and depression scale questionnaire (Zigmond and Snaith, 1983). All subjects received information relating to the research through communication with the researcher and information sheets, after which formal consent was obtained. Participants were tested and scanned at the SFC Brain Imaging Research Centre (www.sbirc.ed.ac.uk), Division of Clinical Neurosciences, University of Edinburgh, a core area of the Wellcome Trust Clinical Research facility and part of the SINAPSE (Scottish Imaging Network- A platform of Scientific Excellence) collaboration (www.sinapse.ac.uk) funded by the Scottish Funding Council and the chief Scientists Office.

2.3.2 Stimulus.

Information sheets and consent forms were constructed detailing the same information as in experiment one but including information concerning the scanning procedure and safety requires (see appendix 7). Screening scanning forms were obtained from the SFC Brain Imaging Research Centre (www.sbirc.ed.ac.uk) at the Western General Hospital and administered to the subjects to ensure each participant was eligible for scanning (see appendix 8).

The same task conditions and hence the same stimuli were used within this experiment as seen in experiment one. However, this time the favourite condition would be considered not just an experimental condition, the task conditions were programmed using Presentation (http://www.neurobs.com/) equipment instead of E-Prime.

Since the favourite condition was not administered within experiment one as having time restraints a few alterations were made to the task condition. This was simply done to by adding an additional image to the middle of the screen to indicate to the participants when to give their answer. The image that was added was a simple ball which was created in Word (Microsoft Office, 2007), this ball was programmed in the same way as the faces seen within the ToM and the control condition. Therefore, task screen containing a yellow circle would appear for 2.1 seconds after which it was replaced by an identical task screen that now

contained a green circle which was presentation for four seconds. An example of the task stimuli for this condition can be seen in figures 6 and 7.

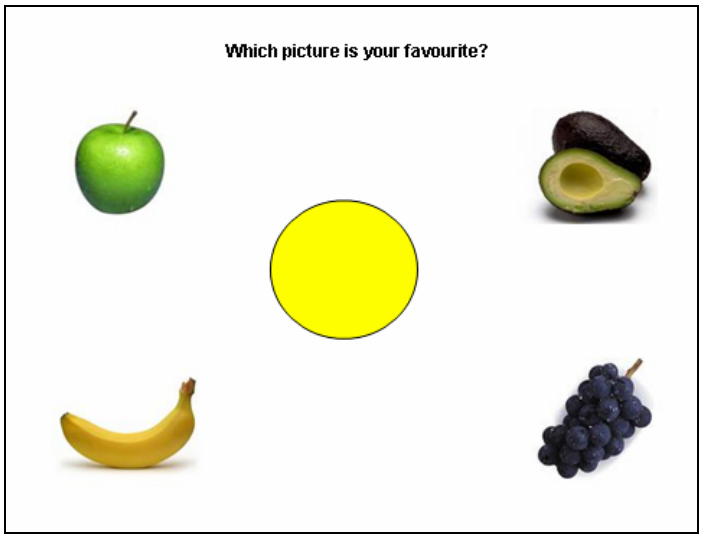

Figure 6: An example of the stimuli used in the favourite condition for the fMRI study, showing a yellow ball.

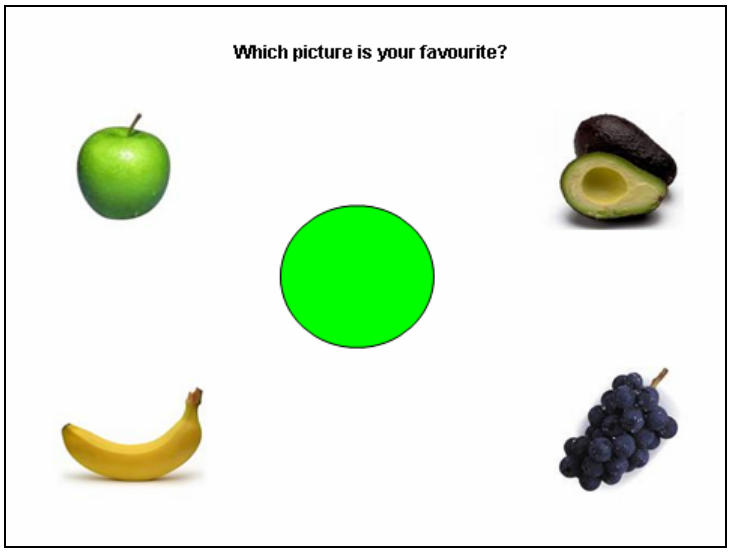

Figure 7: An example of the stimuli used within the favourite condition for the fMRI study, showing the green ball.

Since the favourite condition within experiment one ensured not only that participants favourite picture was noted but that each of the subjects could name the pictures that were presented within the tasks. There was a pre-experimental task constructed for this experiment

to assess the participants naming capabilities for each of the pictures. It was a simple paper task which seen eight portrait A4 pages, containing each of the stimuli pictures, 15 pictures per page. The researcher simple asked the subjects to name each of the pictures, checking each one off and recording the response if somehow different from the researchers name.

Additional equipment was required for use in experiment two as when within the scanner for the tasks to be visible to the participant they required the use of binoculars (http://nordicneurolab.com/) which would be adjusted for their specific requirements. As well as this the responses given by each participant had to be recorded using a microphone compatible with the MRI machinery. This equipment was funded through the SINAPSE collaboration (www.sinapse.ac.uk). The microphone was programmed in line with the various tasks to record for the four seconds that the face or ball was green. Hence at this stage no scanning was taking place and the scanner would have been quite.

2.3.3 Procedure

The participants were greeted by the researcher on arrival to the MRI unit at the Western General Hospital. At this stage they were taken through to an office area within the MRI unit where the researcher informed them that they would have some assessments and forms to complete, after which the radiologist will come through to go over the screening scan form with them. The subjects were given an information sheet and consent form to read and complete before testing. They were then asked to complete a screening scanning form for the experimenters' records and for the radiologists. The participants were then asked if they had any questions concerning the study. Finally they were asked to complete the Hospital and Anxiety questionnaire (Zigmond and Snaith, 1983) before the WTAR assessment (Weschler, 2001) was administered to them.

Once all the correct forms were complete and initial assessments complete, the researcher informed the participant that they were now going to complete the first task which was straightforward and simple. They were going to see a number of pictures, these pictures would be appear in the tasks that they would complete within the scanner. They were asked to name each of the pictures and whilst the researcher noted their responses. The aim here was to ensure that they could name each of the pictures. Once this task was complete the researcher informed the radiologist that they had finished with pre-assessment and the subject was ready for the safety procedure information.

The radiologist would check through each of the questions noted in the screening scan form with the individual, once qualified as being safe to take part in fMRI scan the participant would be taken through to scanner. The radiologist would proceed with fixing the individual into position. This included ensuring they were comfortable, the binoculars were appropriately positioned, the microphone was tapped into place and controlling for any movements.

2.3.3.1 Favourite Procedure

The instructions for each condition were displayed prior to the task itself, the participants were asked to inform the radiologists once they were finished with the instructions as they would move the instructions forward from control room. Once all instructions were complete the radiologist checked that participant understood the instructions. After instructions they were given 5 practise trials concerning the task. They were then asked if they understood the task. Once competent in the task the real task began.

2.3.3.2 Theory of Mind Procedure

Once the first task condition was complete the participant was informed that they would now see further instructions for the next task. Reminded to let radiologist know once they had finished instructions as these would be moved forward by individual in control room. Once instructions complete they were informed that task would start shortly. The task would then run and followed the same procedure as the theory of mind task seen in experiment one.

2.3.3.3 Control Condition Procedure

Same procedure as above condition was followed. Except that once complete the subject was informed that tasks were now complete but as discussed a further scan is being obtained, therefore remain still and silent whilst noise continues around you.

2.2.7 Ethical Issues

Ethical approval was granted by both the NHS ethic committee and the University of Edinburgh's ethical committee. Each participant was informed that they could withdraw from the study at any stage throughout the experiment and formal consent was obtained prior to commencing experiment. Since this experiment involved an fMRI participants were screened before scanning took place ensuring they were eligible for scanning and healthy and safety requirements were followed. After the experiment was complete the participants were fully debriefed.

2.1.4 Task Design

During the scanning phrase, instructions and the tasks were presented visually via binoculars (http://www.nordicneurolab.com/) using Presentation software (http://www.neurobs.com/).

Each condition was presented in separated fMRI sessions using an alternating block design (task vs. rest). The participants were presented with each of the conditions within the same sequence, as each of the conditions ran consecutively, with the Favourite condition running first, followed by the ToM condition and finally the Control condition. Each condition contained ten blocks with 5 trials per block. Each block condition lasted for 9.14 minutes, with each activation block lasting 52.8 seconds, resting block lasting 19.8 seconds .Each trial lasted 6.6 seconds long and consisted of a fixation cross presented for 500 milliseconds following by the task screen displayed for 2.1 seconds. This task screen then changed (face would change from yellow to green) to indicate to the participant to give their verbal response, during this time the scanner was quite and they had 4 seconds to give their answer (spare sampling acquisition). In addition to brain activity being monitored using fMRI, the participants' responses were recorded to measure their accuracy and error type. The response was recorded using an MRI compatible microphone and the recording period lasted 4 seconds. As mentioned earlier, no data were acquired during this period allowing participants to verbally respond whiles minimizing MRI motion artefacts.

2.2.5 Data Acquisition

The imaging work was carried out on a GE 1.5T MRI Signa Horizon scanner at the Scottish Brain Imaging Research Centre (http://www.sbirc.ed.ac.uk/). Following a clinical T2 weighted anatomical image ensuring a absence of brain abnormalities in participants, T2* EPI data (TA= 2600ms; TR=6600ms; TE= 40ms; flip angle=90º; field of view (FOV)= 240mm; matrix size = 64×64; voxel size = 3.75*3.75; number of slices= 30; slice thickness=5mm, interleaved acquisition) with blood oxygenation level dependent (BOLD) contrast were collected parallel to the anterior / posterior commissural plane. Finally, a T1 weighted inversion pulse recovery image was collected (TE= Min full; flip angle=8º; slice thickness=1.3mm; FOV= 240 mm; number of slices= 160; matrix= 192 × 192) at the end of the scanning session. Duration of the scanning was approximately an hour long.

Functional images were acquired over three functional sessions corresponding to the three different tasks (favourite, ToM and control) with a total of 84 images. Per session (9.14

minutes) with the 4 first volumes disregarded prior to analysis to allow for T1 saturation effects.

2.2.6 Data Preprocessing

Data were analysed on a Linux workstation using SPM8 implemented in MATLAB®. Slice timing correction was applied to correct for differences occurring within the images due to acquisition delay between each slice using the 15th slice as reference slice. Images were next realigned to correct for 3D movements (default parameters and 4th degree B-spline interpolation) and normalised to the ICBM space template of the Montreal Neurological Institute (4th degree B-spline interpolation – final voxel size 2x2x2 mm) using parameters obtained via subjects coregistered T1/mean EPI images. Finally, prior statistical analyses, data were smoothed using an 8 mm full width at half- maximum (FWHM) isotopic Gaussian kernel.

2.2.7 Data Analysis

Statistical analysis was carried out using the general linear model with boxcar functions convolved by the canonical hemodynamic response function in order to model each activation block. A design matrix was specified in the first level analysis for each individual with 3 sessions, each one including a regressor of the activation blocks (favourite, ToM and control depending on the session), a parametric exponential (time) expansion and finally motion parameters. In addition data were high-pass filtered with a cut off at 128sec and low passed via a 1st order autoregressive model. After fitting the GLM, beta parameters for each regressors were obtained and incorporated within the second level analysis.

For the group analysis (random effects), beta parameters of each subjects were entered into two separate repeated measure ANOVA. For each ANOVA the three tasks were compared through planned contrasts between the ToM and Control tasks and between the ToM and Favourite tasks. In the 1st ANOVA, parameters modelling each of the tasks were used whereas in the second ANOVA, parameters modelling the time effect in each of the tasks were used. Given the small sample analyzed (N=5), a voxel was deemed significant for p values < 0.01 uncorrected. In addition, a cluster size of more than 10 contiguous voxels was applied.

Results were visualized on the averaged 152 T1 template and activation labelling obtained using the anatomy toolbox (Eickhoff et al., 2005, 2006 (http://www.fzjuelich.de/ime/spm_anatomy_toolbox.) which is based on observer –

independent cytoarchitectonic analysis of 10 post mortem brains to provide stereotaxic information on the location and variability of the cortical areas in the MNI space. Figures are presented using the neurological convention.

3. Results

This section analyses the data that was obtained during the scanning study. Analysis considering the accuracy scores for the ToM condition and control condition was conducted on PASW 17.0, with the significant level set $P<0.05$ (2-tailed).

3.1. Accuracy scores Analysis.

Table 3 illustrates the raw accuracy scores for each participant within the two task conditions (ToM and control). Table 4 depicts the average and standard deviations for the group concerning their age and accuracy scores for the two task conditions (ToM and control).

Table 3: Raw scores for the ToM condition, control condition and participants' ages.

Participants	1	2	3	4	5
Age (years)	50	52	56	61	40
ToM condition	49	50	50	49	50
Control condition	50	50	50	50	50

Table 4: Means and Standard Deviations for the group concerning age, ToM condition and control condition.

	Age	ToM condition	Control condition
Mean (S.D)	51.8 (7.82)	49.6 (0.55)	50 (0.00)

The mean accuracy scores for the two task conditions were compared using a non-parametric significance test as there were only a small number of participants and ceiling effects within the two conditions, this was to analysis if the mean accuracy score in the ToM condition significantly differed from the accuracy score in the control condition. Results indicate that there is no significant difference between the mean accuracy score for ToM and control task condition $U= -7.5$, $n_1=n_2=5$, $P=0.721$. As shown in Table 3 there were two individuals who made errors within the ToM condition, whilst no errors were made on the control condition. These errors occurred at different trials within the ToM task and were noted as being favourite errors.

3.2 Functional Imaging Analysis

3.2.1 Overall ANOVA (all conditions vs. baseline)

An overall ANOVA was conducted to analyse all the task conditions versus the baseline, this contrast showed that there was a significant difference in BOLD responses in the inferior parietal cortex, right insula lobe and the left hippocampus when compared to the baseline. (see figure 5 and table 6). For a full list of activations please see appendix…

Table 5: Large clusters where brain activations were elicited for all conditions vs. the baseline.

	MNI coordinates					
Area of activation	x	y	z	Z	F	Cluster size (voxels)
Inferior parietal cortex	40	-38	32	4.06	52.89	274
Right insula lobe	34	-18	10	4.08	53.87	204
Inferior parietal cortex (left supramarginal gyrus)	50	-38	28	3.54	52.89	145
Left hippocampus	-24	-30	-8	4.90	148.29	142

Height threshold: F= 8.65, P=0.01 (uncorrected); extent threshold: k= 10 voxels.

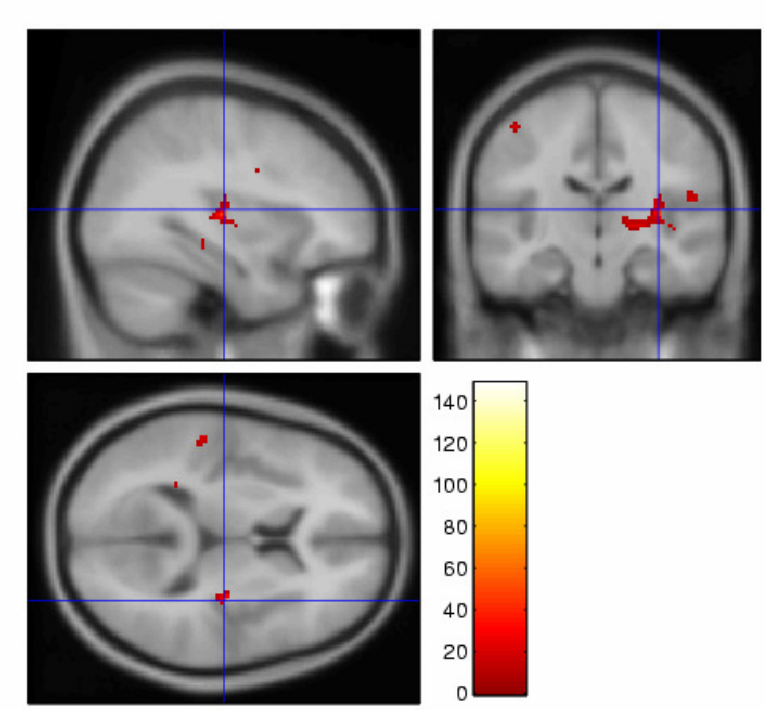

Figure 8: Activations in the three conditions vs. baseline in the insula lobe. The cross hairs were centred on MNI coordinates 34, -18, 10.

3.2.2. Group Comparison ANOVA for conditions (Favourite vs. ToM vs. Control)

A further comparison considered the groups' neural response for each of the task conditions (Favourite vs ToM vs Control). Results showed that there were significant difference in BOLD activations between the three task conditions within the hippocampi, insulae and inferior parietal lobes. Table 7 shows the largest clusters within the brain that showed significant differences (see appendix XX for a full list of the areas where neural activation between the conditions was different).

Table 6: Brain areas where significantly different BOLD responses were found for the three different conditions.

Area of activation	MNI coordinates x	y	z	Z	F	Cluster size (voxels)
Left hippocampus	-24	-30	-8	4.90	148.29	142
Right insula	34	-18	10	4.08	53.87	204
Inferior parietal cortex	40	-38	32	4.06	52.89	274
Inferior parietal cortex	-50	-38	38	3.54	29.54	145

Height threshold: F= 8.65, P=0.01 (uncorrected); extent threshold: k= 10 voxels.

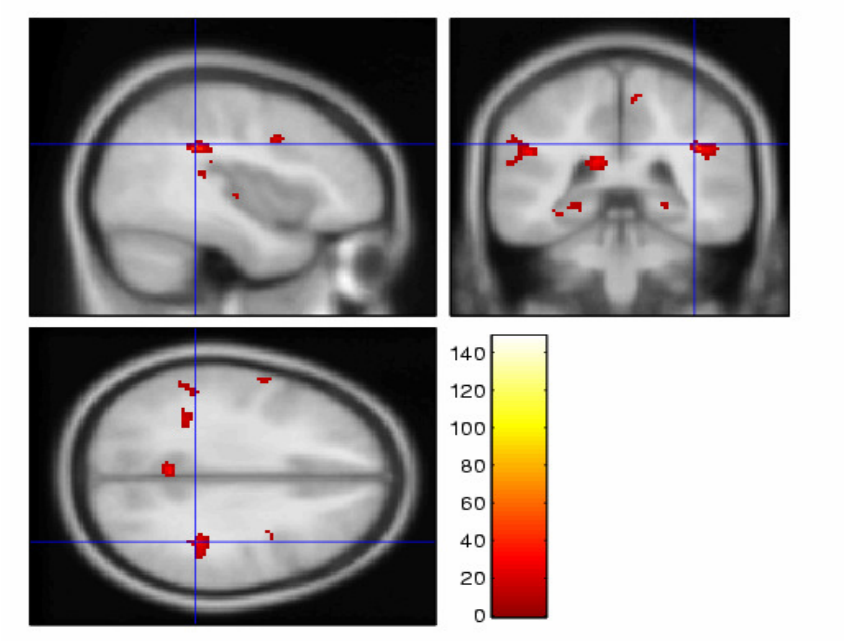

Figure 9: Activations when comparing the three conditions against each other, significant difference in BOLD responses was found in the inferior parietal lobe. The cross hairs are centred on MNI coordinates 40, -38, 32.

3.2.3. ToM vs. Control condition.

To investigate if the ToM condition elicited neural activations which were different from those produced in the control condition, these two conditions were contrasted against

each other, revealing areas of significant difference within left/right hippocampi, right superior temporal gyrus and some small clusters of activation in the insula (table 8).It appears that these differences were due to decreased ToM activations within these areas, whilst the control saw increased BOLD responses within these areas.

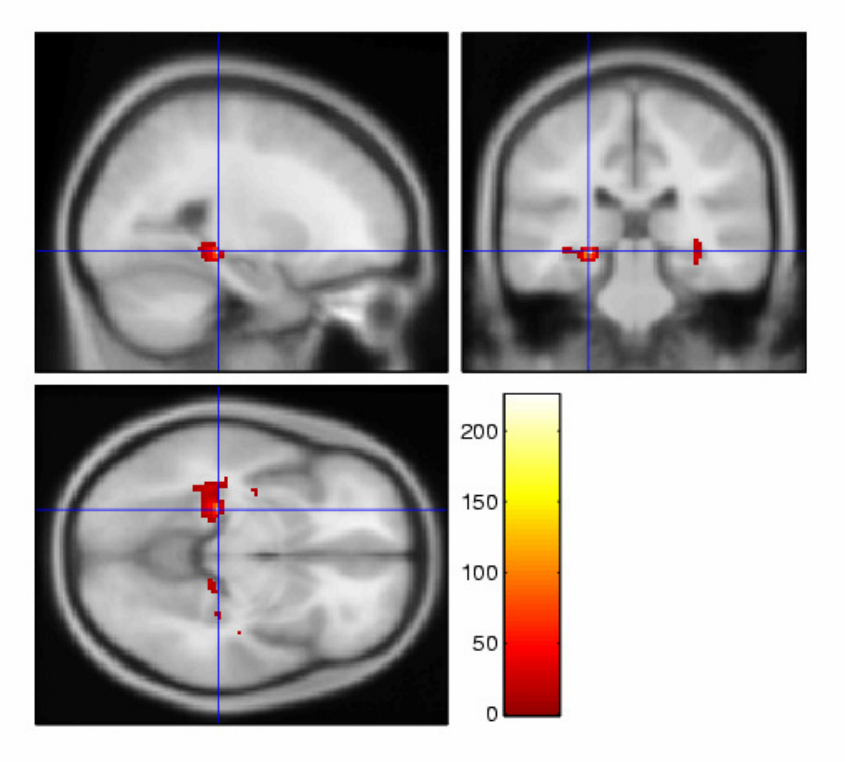

Figure 10: Significantly different activations found in the left hippocampus when comparing the ToM condition versus the control condition. The cross hairs are centred on MNI coordinates -24, -30, -8.

3.2.4 Favourite Condition vs. ToM condition.

Further analysis was considered to test if the neural areas activated during the ToM condition were significantly different from those activated during the favourite condition. Significant differences with an increase for the ToM condition relative to favourite condition were found in the inferior parietal cortex, insulae, amygdala and a small cluster of activation in the left STG (table 8 and figure 9).

Table 7:Larger clusters of brain activations during different contrasts.

Contrast(s)		MNI coordinates					
	Areas of activation	x	y	z	Z	F	Cluster size (voxels)
ToM vs Control	Left Hippocampus	-24	-30	-8	4.94	224.78	203
	Right ParaHippocampal Gyrus	32	-30	-12	3.14	26.90	98
	Superior Temporal Gyrus	40	-34	14	2.98	22.58	43
Favourite vs ToM	Right Insula lobe	34	-18	10	4.21	90.07	288
	Inferior Parietal lobe	42	-36	30	4.12	80.27	290
	Inferior Parietal lobe	-50	-38	28	3.78	54.10	149
	Amygdala	-30	-10	0	3.39	35.15	105

Height threshold: F=11.26; P=0.01(uncorrected); extent threshold: k=10 voxels.

3.3.5 ANOVA on time regressors

This study we also considered the effect of time over the three conditions. However, no large clusters of activations were observed.

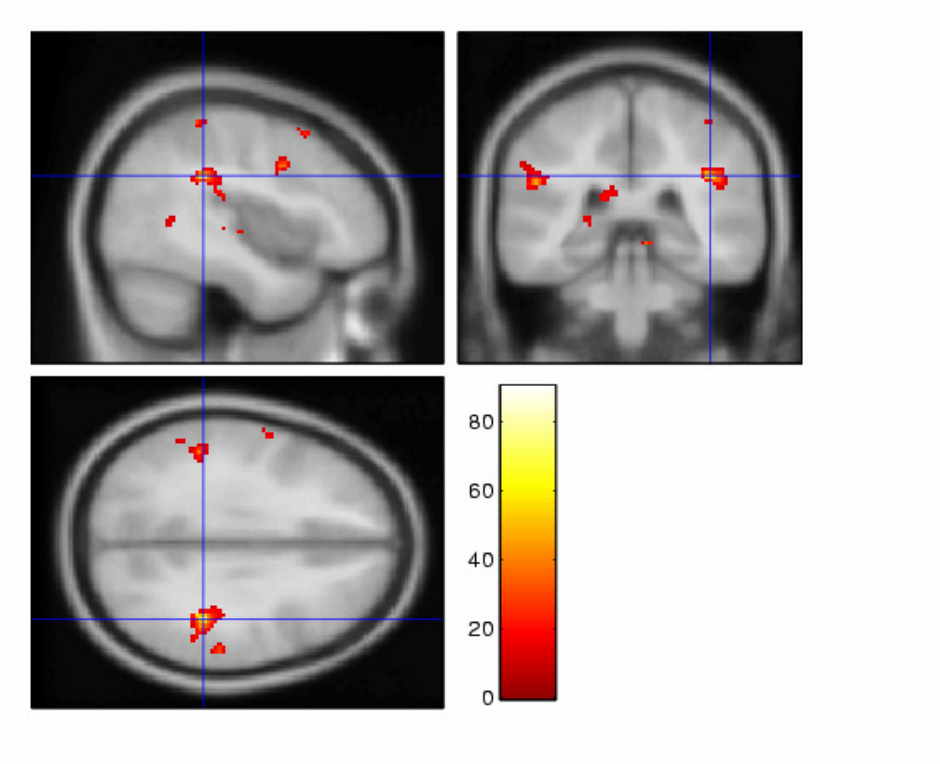

Figure 11: Activation within the inferior parietal cortex when considering favourite condition versus the ToM condition. The cross hairs are centred on MNI coordinates 42, -36, 30.

4. Discussion

One of the crucial aims of this research was to ensure that the eye gaze task developed was compatible with an fMRI scanner sequence and that the participants' responses were being made at the appropriate time to elicit neural activity. This study has clearly fulfilled this aim as the results show how there are neural activations for the tasks which are significantly different from those neural activations that are elicited during the baseline condition. These differences were found in the inferior parietal cortex, right insula lobe and the left hippocampus. As well as this the participants' responses were assessed in terms of accuracy and error types. Essentially this means that this eye gaze preference task can be utilised in further research investigating the neural basis of ToM.

One of the aspects which was analysed within this research was whether there was a significant difference between the mean accuracy score for the ToM condition compared to the control condition. After analysis results indicate that as predicted that there is no significant difference between these two mean accuracy scores. This is a logical finding as the participants within the study were all assessed and found to be typically healthy individuals. Therefore they all have the ability to infer which of the pictures the face likes best from the eye gaze cues as well as having no problems with detecting eye gaze direction. Hence it could be possible that direct and mutual gaze are a perquisite of our social interactions (Baron-Cohen et al., 1997; Emery et al., 2000) as this task uses simple eye gaze cues to infer another's mental state. So as suggested by Baron-Cohen et al (1997; Emery et al., 2000) eye gaze could be a crucial building block within our mentalising development. This section of the results replicates previous research using the eye gaze preference task such as Snowden et al., (2003; Shamay- Tsoory et al., 2007) as when considering the accuracy scores of their controls with their eye gaze preference task they found that ceiling effects were reached within the ToM conditions and their control conditions, hence no significant difference was found between their mean accuracy score for either condition, just as seen in this piece of research.

Although ceiling effects were noted within the results there were a couple of errors made, these occurred within the ToM condition i.e. when the individual had to judge which picture the face liked best from the faces' eyes. Errors evidently occurred when the participant picked a picture that the face was not looking at as the one that the face liked best. Although only two of these errors were made they were made by different participants and at

different trials within the task. One error occurred at the beginning of the task condition whilst the other occurred straight after the first rest period. One hundred percent of the errors made within the fMRI study were classified as favourite errors as described in the Snowden et al. (2007). Meaning that the errors were occurring due to the participant simply saying which picture was their personal favourite. Snowden et al. (2007) describe the favourite error in terms of their FTD patients as a numerous amount of their errors tended to relate to their personal favourite picture. They reasoned that this was due to their inability to inhibit their favourite response or alternative that FTD patients live within their own egocentric world and so fail to recognise or attribute others mental states when they differ from their own (Snowden et al., 2003). Within this study although the participant is choosing their personal favourite picture when these favourite errors occur, it is most likely that the subject is adjusting to the new instructions required from the task. Evidence for this can be seen in when the errors occur within this condition, as one error occurred straightway whilst the other occurred after the first rest period, here the participants may have briefly forgot the new instructions for the task, therefore reverting back to the previous task condition of which picture they liked best.

The errors within the fMRI study can all be classified as favourite errors but this was not the case for the pilot study, as the two errors within this study were unclassified. The two errors made during this experiment were made by the same individual and both occurred within the ToM condition. It is suggested that these errors could be related to the fact that the individual was choosing the most dominant picture. Dominance in this sense refers to the picture which stood out the most within the combination of pictures e.g. the picture that had the brightest colours.

As mentioned one of the main aims of the study was to pilot the eye gaze preference task within an fMRI study as this task was novel to that particular environment. However, a secondary aim of the study was to consider which brain areas were activated during this ToM task, these areas could then be considered as potential regions which are specific for our ToM skill. At the start of the study it was suggested that perhaps significant increases in neural activations for the ToM condition would be found within the mPFC/OFC (Baron-Cohen 1999; Gallagher et al., 2000; Gallagher et al., 2003), TPJ (Saxe et al., 2003; 2005; 2008), Temporal Poles (Gallagher et al., 2003), STS/STG (Baron-Cohen et al., 1999; Gallagher et al., 2002) or the amygdala (Brunet et al., 2000; Mitchell et al., 2005) as these are all areas which have been noted by previous brain imaging studies as specific for our ToM abilities.

To investigate this within the present study we compared the neural responses elicited during the ToM condition task against BOLD response found in the control condition task. Significantly different neural responses were noted in the left/right hippocampi, right superior temporal gyrus and the insula. It appeared that these areas were where there was a decreased activation for the ToM condition when compared with the control condition. So although studies have speculated that the STG and Insula are involved in ToM processes (Baron-Cohen et al., 1999; Brunet et al., 2000; Grezes et al., Mitchell et al., 2005) it appears within these studies they were more activated during the control condition. One of the reasons why the STG may have been more responsive during the control condition was that participant was making decisions purely based on eye gaze, no emotional judgment was required. The participant was being explicitly told to pick which picture the face was looking at, as previous research has suggested that the STG is involved in eye gaze detection (Brothers 1990; Itier & Batty, 2009).

As well as these areas there was a significant difference found in the left and right hippocampi when comparing these two task conditions, again this area has not been noted within any of the brain imaging literature reviewed within the introduction. The hippocampus is often linked with our memory function (Squire, Ojemann, Miezin, Peterson, Videen and Racichle, 1992) like the other two neural areas it was noted that the difference was due to increased activations for control condition. It is unsure why the hippocampi would have been differently activated in these two tasks. Perhaps it is due to the fact that the control condition was the last condition to be presented to the subjects therefore they could have been remembering certain associations made within the first two conditions with the pictures e.g. perhaps the pictures were triggering their personal memories from which one was their favourite picture.

Unfortunately it seems that the study failed to note any specific increases in neural activations for the ToM condition when comparing it against the control condition.

However, the study also compared the BOLD responses from the ToM condition against the BOLD responses from the favourite condition to investigate if there were any areas which responded differently to these two conditions. Results found that there were significantly different BOLD activations within the inferior parietal cortex, insula, amygdala and left STG when comparing these two conditions. It appeared that the ToM condition when compared to the favourite condition was eliciting increased neural responses within these

specified areas. All of these areas have been noted in previous brain imaging research as responding when tasks assess our ToM ability (Fletcher et al., 1995; Baron-Cohen et al., 1999; Mitchell et al., 2005; Saxe et al., 2003; Grezes et al., 2004).

The amygdala is often associated with the ability to detect emotions (Brothers, 1990; Morris et al., 1996) therefore perhaps the ToM condition increased activations within this area were due to the fact that face was expressing a happy emotion and they were recognising this. It is not surprising that decreased activations were found within this region for the control condition as in this condition no face was displayed and therefore no emotion had to be recognised. The inferior parietal cortex has been linked with theory of mind research as there are several studies which have found activations within this area specific for ToM (Brunet et al., 2000; Gallagher et al., 2002; Kobayashi et al., 2007). Therefore perhaps this area is an important region of ToM process, as within the current research when compared to the favourite condition higher BOLD responses were found in this region. The inferior parietal cortex is one of the sites known to contain mirror neurones (Gallase & Goldman, 1998), these neurones are theorised to be behind one of the suggested strategies of how we conduct our mentalsing skill. This strategy is known as the simulation theory of mentalising and involves the idea that these neurones help us to infer others' mental states by comparing their mental states with our own (Gallase et al., 2004). Therefore perhaps this is why this regions was activated within the ToM condition as these neurones were implementing the simulation strategy. Finally the STG as noted earlier is associated with the detection of eye gaze therefore it seems appropriate this area is more activated in the ToM condition than the control, as the control condition requires no detection of eye gaze direction as no faces or eyes are involved within the stimuli.

Although different neural responses have been noted within the study for the different tasks none are the areas which are thought to be central to our ToM capabilities as stipulated by other brain imaging studies. The differences in neural responses found within this study and others could have been related to the fact that this task was designed to rely less on language and executive functioning therefore this could have lead to different neural responses to process ToM. One has to remember that this task is novel to an imaging environment therefore it is difficult to say which brain regions should or should not have been activated.

4.1. Limitations within the study

A potential weakness of the study as there is within any brain imaging study is that the fMRI relies on the assumption that different areas are related to qualitatively differences in psychological processes (Overwalle, 2009). But this assumption is not necessarily true (Henson, 2006; Saxe, Carey & Kanwisher, 2004). As brain regions are constructed of thousands of neurones, each of these neurones could have distinct functions which unfortunately cannot be teased apart with the current technique (Overwalle, 2009). As well as this one can never be 100% sure that the individual within the scanner is indeed concentrating solely on the task as they may be considering other factors e.g. something that happened earlier within that day.

Another obvious limitation within the current research is that there were only 5 participants scanned for the fMRI study, this is too few people to exclusively conclude from the results which brain areas are activated for this theory of mind eye gaze preference task. As perhaps with more controls there would have been different results, in the sense that more areas may have been significantly activated and perhaps these areas would have been areas in which the ToM condition had a significant increased neural response. Therefore it is suggested that further research considers administering this to more control participants to remove any doubt over results collected by this study due to lack of participant numbers.

The fact that the task used within this study is novel to an fMRI environment in itself causes limitations, as the results cannot be adequately compared to previous brain imaging research as no other brain imaging studies have utilised this particular task. Therefore brain activations elicited from a simple eye gaze preference task are being compared to neural responses from complex story tasks, although both assessing our mentalising ability, the story task shall have interference from brain regions which are recruited for other processes e.g. our language understanding.

The task itself may be a limitation when considering which brain regions are activated during ToM. As its sensitivity has been questioned previously by Shamay-Tsoory et al (2007), as ceiling effects were found in accuracy scores for this study as were they found within the present research. Perhaps the fact that the task is a first order ToM task means that the neural regions required to process it are the more peripheral brain regions found within the ToM literature.

4.3 Future Research/Directions

Firstly an extension of this study should be commenced as this research only scanned five control subjects, perhaps with a larger control population one would be able to say with more confidence which areas are said to be activated in the this ToM eye gaze preference task. Therefore suggesting which areas are involved in our ToM aptitude.

Future research should perhaps consider using this eye gaze preference task within a clinical population in combination with brain imaging techniques. As Shamay-Tsoory et al., 2007 have already shown how this task is sensitive enough to show problems within schizophrenia patients and Snowden et al., 2003 have proven that FTD patients have significant problems with this task. It therefore would be interesting to note how they perform these tasks within a scanning environment. Girardi et al., 2010 have also monopolised this task within their MND study to highlight how variants of MND patients not only have non-social cognitive impairments but can also have emotional and social cognition deficits. Using the ToM eye gaze preference task within a brain imaging context to consider different clinical populations may help to highlight where the specific brain abnormalities occur within these clinical populations. In turn this could lead to help with future diagnosis and treatment plans.

The present study did consider the possibility that different brain regions are perhaps activated during our own favourite choose as compared to those activated when inferring others' favourite chooses. However, this paper did not consider comparing the eye gaze preference task to other ToM tasks. As this is an exploratory study to consider if this task could adequately work within the confounds of an fMRI perhaps future research could consider if the neural activations elicited during this task are significantly different from brain regions excited within other ToM tasks.

The task within this current experiment was considered to be a first-order ToM task, perhaps future research could expand this task to include second-order conditions. This may also counteract any problems which could have been due to the first-order task not being sensitive enough. A variety of eye gaze tasks could be constructed to assess the idea of cognitive and affective ToM abilities within a imaging paradigm, perhaps these could be adapted from thus seen in Shamay-Tsoory et al.,(2007) study. These paradigms could then lend evidence to the idea that ToM should be defined as two separate components.

If possible future research should not only note the responses and errors made by the individual within this task but consider their reaction times for their responses within the

conditions as this as be noted to be a more sensitive method in the detection of differences between ToM and control conditions (Shamay-Tsoory et al., 2007).

Perhaps with future studies the face could be developed into a more human like face in an attempt to make the task more ecologically valid.

4.4. Conclusion

In conclusion it appears that this particular 'Theory of mind' eye gaze preference task can indeed be used within a scanner environment. Therefore this task can be utilised in future research studies which wish to consider which areas of the brain are correlated with our ToM processes, whilst at the same time minimise the executive functions which are required to complete the task. However, unlike previous studies which have often referred to the importance of the mPFC /OFC and the TPJ (Gallagher et al., 2000; Baron-Cohen et al., 1999; Saxe et al., 2003; Gallagher et al., 2003) within our mentalising ability, this study was unable to implicate any areas which showed specific increases in neural activity for the ToM condition when compared to the control condition. Nevertheless it did pinpoint some areas that were activated differently when making decisions concerning our own favourite choices and inferring others' favourite choices. As mentioned already the study could have failed to replicate previous ToM studies in finding specific activations within the PFC and or in the TPJ for various reasons, one of these major limitations could have been caused by the lack of participant numbers. Therefore immediate studies should seek to assess this ToM assessment tool on more control subjects to counteract any of the limitations caused by lack of subjects After which future research should seek to implement this assessment tool into clinical populations and possibly expand the task to include accepts of second-order ToM skills and cognitive and or affective ToM abilities. Although ultimately the main aim of this study was fulfilled as it adequately piloted the eye gaze preference task within the novel surroundings of an MRI scanner.

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Appendix

Appendix 1: Information Sheet and Consent form for offline Pilot Study.

Psychology

SCHOOL OF PHILOSOPHY, PSYCHOLOGY and LANGUAGE SCIENCES

The University of Edinburgh

7 George Square

Edinburgh

EH8 9JZ

Telephone 0131 650 3440

Direct Line to Dr Abrahams: 0131 650 3339

Email: Psychology@ed.ac.uk

Email Dr Abrahams: s.abrahams@ed.ac.uk

VOLUNTEER INFORMATION SHEET

Study title: "Neural Basis of Theory of Mind.'

You are being invited to take part in a research study. Before you decide it is vital that you understand why the research is being done and what it will involve. Please take the time to read the following information and ensure that you understand all aspects involved, you can discuss this with other if you so wish. Ask if there is information that seems unclear or if you would like more information. Take time to decide whether or not you want to take part.

What is the purpose of the study?

Some neurological conditions can result in changes in emotions and behaviour. There are various methods which have been used to investigate these changes in emotions and behaviour, using one such method we are hoping to underpin the reason behind these changes in behaviour and emotion.

Why I have been chosen?

We will be seeing a total 8 control participants.

Do I have to take part?

It is completely your decision whether or not you take part in the above experiment. If you do decide to take part you shall be asked to keep this consent form and asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

If you decide to take part in the study you will be asked several background questions.

All volunteers will be asked to perform a number of tasks, these tasks are straight forward and simple. They involve viewing objects on a laptop screen and being asked to choose an object according to the instructions you are given. The tasks will require you to answer verbally aloud and your answers will be recorded by the experimenter. The task will require around 30 minutes of your time and you will be reimbursed for our time with £6.00.

What do I have to do?

You do not have to take any medication or undergo any invasive procedure whatsoever.

During the your session with the experimenter you will be given instructions for each of the tests prior to beginning them.

What are the possible disadvantages and risks of taking part?

If you feel distressed at any time during the process, it is important that you let the experimenter know straight away. If you feel distressed after the experiment, please contact Dr. Sharon Abrahams 0131 650 3339.

What are the possible benefits of taking part?

There will be no direct benefit to you by taking part, and your individual results will not be revealed to you. However, it is hoped that the research will improve the understanding of the changes in emotions and behaviour that individuals with different disorders experience and may influence care practices in the future.

What if something goes wrong?

Whilst we do not anticipate any adverse effects from taking part in the study, if you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for legal action but you have to pay for it. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, the normal National Health Service complaints mechanisms should be available to you.

Will my taking part in this study be kept confidential?

All the information collected about you will be kept strictly confidential. Any information about you will have your name and corresponding information removed so that you cannot be recognised from it.

What will happen to the results of the research study?

The results will be involved in a MSc research project.

Who is organising the research?

The study is being organised an MSc student, Nicola Elder who is currently attending Edinburgh University and Dr. Sharon Abrahams from the University of Edinburgh and Lothian Clinical Neuropsychology Unit at the Royal Edinburgh Hospital.

Who has reviewed the study?

This study has been reviewed by ethics committee in the NHS and the Psychology department of Edinburgh University.

Contact for further information

If you wish to ask anything further, please contact Dr. Sharon Abrahams via the address below:

Department of Psychology, PPLS

7 George Square

Edinburgh,

EH8 9JZ.

OR via the following telephone numbers or email addresses:

Dr. Abrahams on 0131 650 3339 (s.abrahams@ed.ac.uk)

Thank you for reading this information sheet. You will be given a copy to keep. If you have understood the contents of this sheet and wish to take part, please complete the consent sheet on the next page. If you have any questions feel free to ask them now.

CONSENT FORM- Confidential

Title of project: Neural Basis of Theory of Mind

Name of Researcher: Nicola Elder *Please initial box*

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that my voice will be audio taped for the purpose of the study. ☐
4. I agree to take part in this above study. ☐

Name of Participant	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

Appendix 2: Favourite Recording Sheet

Recording sheet for Favourite task

Name:

Date of Birth:

Contact no.:

Participants answers circled.

Category	**Upper Left**	**Upper right**	**Bottom Left**	**Bottom Right**
Vegetables	Lettuce	Butternut Squash	Peas	Parsnip
	Corn	Beetroots	Cabbage	Asparagus
	Cucumber	Potato	Celery	Spinach
	Broccoli	Scallions	Tomato	Carrots
	Pepper	Turnip	Cauliflower	Onion
Household items	Dishwasher	Computer	Microwave	Sofa
	Kettle	Stairs	Lamp	Cooker
	Bookcase	Table	Washing Machine	Armchair
	Toilet	Bedside Cabinet	Sink	Chair
	Bath	T.V.	Wardrobe	Bed

Cartoons	Donald	Homar	Micky	Simba
	Daffy	Shrek	Winnie	Pluto
	Snow White	Minnie	Bugs	Peterpan
	Bart	Tigger	Little Mermaid	Fred Flintstone
	Bambi	Tinkerbelle	Donkey	Nemo
Fruits	Blueberry	Cherries	Kiwi	Lime
	Apple	Avocado	Banana	Grapes
	Prunes	Mango	Peach	Raspberries
	Strawberry	Orange	Lemon	Pear
	Pineapple	Plum	Melon	Cranberries
Animals	Butterfly	Goat	Penguin	Tiger
	Dog	Horse	Whale	Lion
	Chicken	Goldfish	Pig	Rabbit
	Ape	Frog	Parrot	Sheep
	Cat	Elephant	Mouse	Shark
Household Items	Cooker	Lamp	Washing Machine	Sofa
	Bedside Cabinet	Kettle	Stairs	Toilet
	Table	T.V.	Bookcase	Bath
	Dishwasher	Armchair	Chair	Computer
	Sink	Wardrobe	Bed	Microwave
Fruits	Avocado	Kiwi	Raspberries	Plum

	Banana	Blueberry	Melon	Orange
	Pear	Apple	Mango	Lime
	Peach	Strawberry	Prunes	Grapes
	Cranberries	Lemon	Pineapple	Cherries
Animals	Cat	Penguin	Rabbit	Sheep
	Elephant	Goat	Horse	Mouse
	Whale	Parrot	Butterfly	Lion
	Shark	Tiger	Chicken	Dog
	Frog	Ape	Goldfish	Pig
Vegetables	Corn	Celery	Cabbage	Cauliflower
	Lettuce	Cucumber	Tomato	Scallions
	Carrots	Turnip	Potato	Onion
	Butternut Squash	Parsnip	Broccoli	Spinach
	Beetroot	Asparagus	Peas	Pepper
Cartoons	Micky Mouse	Bambi	Peterpan	Minnie
	Daffy	Donald	Snow White	Shrek
	Homar	Tigger	Fred Flintstone	Winnie
	Nemo	Pluto	Bugs	Donkey
	Little Mermaid	Tinkerbell	Simba	Bart
Practice	Duck	Owl	Hedgehog	Cow
	Snake	Bee	Seal	Crab

	Monkey	Starfish	Wolf	Camels
	Zebra	Giraffe	Squirrel	Donkey
	Lizard	Bear	Deer	Ladybug

Practice Session

Practice	**Duck**	Owl	Hedgehog	Cow
	Snake	Bee	Seal	**Crab**
	Monkey	**Starfish**	Wolf	Camels
	Zebra	Giraffe	Squirrel	**Donkey**
	Lizard	Bear	**Deer**	Ladybug

Appendix 3: Theory of Mind Recording Sheet.

Recording sheet for 'Like Best' (Theory of Mind) task

Name:

Date of Birth:

Contact no.:

Participants answers circled.

Category	Upper Left	Upper right	Bottom Left	Bottom Right
Fruits	Apple	Avocado	**Banana**	Grapes
	Blueberry	**Cherries**	Kiwi	Lime
	Prunes	Mango	Peach	Raspberries
	Strawberry	Orange	Lemon	**Pear**
	Pineapple	Plum	Melon	Cranberries
Cartoons	Bart	Tigger	**Little Mermaid**	Fred Flintstone
	Bambi	**Tinkerbelle**	Donkey	Nemo
	Donald	**Homar**	Micky	Simba
	Daffy	Shrek	Winnie	**Pluto**
	Snow White	Minnie	Bugs	Peterpan
Vegetables	Beetroot	Asparagus	Peas	**Pepper**
	Butternut Squash	Parsnip	**Broccoli**	Spinach
	Carrots	**Turnip**	Potato	Onion
	Lettuce	Cucumber	Tomato	**Scallions**
	Corn	Celery	**Cabbage**	Cauliflower
Household items	**Bath**	T.V.	Wardrobe	Bed
	Toilet	Bedside Cabinet	Sink	Chair
	Bookcase	Table	Washing Machine	**Armchair**
	Kettle	Stairs	**Lamp**	Cooker
	Dishwasher	**Computer**	Microwave	Sofa
Animals	Cat	**Elephant**	Mouse	Shark
	Ape	Frog	Parrot	**Sheep**
	Butterfly	Goat	Penguin	Tiger
	Chicken	Goldfish	**Pig**	Rabbit
	Dog	Horse	Whale	**Lion**
Cartoons	Little Mermaid	Tinkerbelle	Simba	**Bart**
	Nemo	Pluto	Bugs	Donkey
	Homar	Tigger	**Fred Flintstone**	Winnie
	Daffy	Donald	Snow White	**Shrek**
	Micky Mouse	**Bambi**	Peterpan	Minnie

Animals	**Cat**	Penguin	Rabbit	Sheep
	Shark	Tiger	**Chicken**	Dog
	Elephant	Goat	Horse	**Mouse**
	Frog	**Ape**	Goldfish	Pig
	Whale	**Parrot**	Butterfly	Lion
Household Items	Sink	Wardrobe	Bed	**Microwave**
	Cooker	Lamp	Washing Machine	Sofa
	Bedside Cabinet	Kettle	**Stairs**	Toilet
	Table	**T.V.**	Bookcase	Bath
	Dishwasher	Armchair	Chair	Computer
Fruits	Pear	Apple	**Mango**	Lime
	Avocado	**Kiwi**	Raspberries	Plum
	Cranberries	Lemon	**Pineapple**	Cherries
	Banana	Blueberry	Melon	**Orange**
	Peach	Strawberry	Prunes	Grapes
Vegetables	Broccoli	Scallions	Tomato	**Carrots**
	Cucumber	**Potato**	Celery	Spinach
	Corn	Beetroots	Cabbage	Asparagus
	Lettuce	Butternut Squash	**Peas**	Parsnip
	Pepper	Turnip	Cauliflower	**Onion**

Appendix 4: Control Condition Recording Sheet.

Recording sheet for 'Looking at' (Control) task

Name:

Date of Birth:

Contact no.:

Participants answers circled.

Category	**Upper Left**	**Upper right**	**Bottom Left**	**Bottom Right**
Animals	**Butterfly**	Goat	Penguin	Tiger
	Chicken	Goldfish	**Pig**	Rabbit
	Dog	Horse	Whale	**Lion**
	Ape	Frog	Parrot	**Sheep**
	Cat	**Elephant**	Mouse	Shark
Vegetables	Pepper	Turnip	Cauliflower	**Onion**
	Lettuce	Butternut Squash	**Peas**	Parsnip
	Corn	Beetroots	Cabbage	Asparagus
	Cucumber	**Potato**	Celery	Spinach
	Broccoli	Scallions	Tomato	**Carrots**
Household	Kettle	Stairs	**Lamp**	Cooker

items	Dishwasher	**Computer**	Microwave	Sofa
	Bath	T.V.	Wardrobe	Bed
	Toilet	Bedside Cabinet	Sink	Chair
	Bookcase	Table	Washing Machine	**Armchair**
Fruits	**Peach**	Strawberry	Prunes	Grapes
	Pear	Apple	**Mango**	Lime
	Avocado	**Kiwi**	Raspberries	Plum
	Cranberries	Lemon	**Pineapple**	Cherries
	Banana	Blueberry	Melon	**Orange**
Cartoons	**Nemo**	Pluto	Bugs	Donkey
	Homar	Tigger	**Fred Flintstone**	Winnie
	Daffy	Donald	Snow White	**Shrek**
	Micky Mouse	**Bambi**	Peterpan	Minnie
	Little Mermaid	Tinkerbelle	Simba	**Bart**
Vegetables	Beetroot	Asparagus	Peas	**Pepper**
	Corn	Celery	**Cabbage**	Cauliflower
	Butternut Squash	Parsnip	**Broccoli**	Spinach
	Lettuce	Cucumber	Tomato	**Scallions**
	Carrots	**Turnip**	Potato	Onion

Animals	**Cat**	Penguin	Rabbit	Sheep
	Elephant	Goat	Horse	**Mouse**
	Whale	**Parrot**	Butterfly	Lion
	Shark	Tiger	**Chicken**	Dog
	Frog	**Ape**	Goldfish	Pig
Household Items	**Cooker**	Lamp	Washing Machine	Sofa
	Table	**T.V.**	Bookcase	Bath
	Sink	Wardrobe	Bed	**Microwave**
	Dishwasher	Armchair	Chair	Computer
	Bedside Cabinet	Kettle	**Stairs**	Toilet
Cartoons	Bart	Tigger	**Little Mermaid**	Fred Flintstone
	Snow White	Minnie	Bugs	Peterpan
	Daffy	Shrek	Winnie	**Pluto**
	Donald	**Homar**	Micky	Simba
	Bambi	**Tinkerbelle**	Donkey	Nemo
Fruits	Blueberry	**Cherries**	Kiwi	Lime
	Apple	Avocado	**Banana**	Grapes
	Pineapple	Plum	Melon	Cranberries
	Strawberry	Orange	Lemon	**Pear**
	Prunes	Mango	Peach	Raspberries

Appendix 5: Pictures Sourced for Stimuli.

Practice Trials Pictures:

















Vegetable Pictures:















Household Pictures:



















Cartoon Pictures:







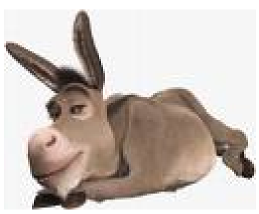
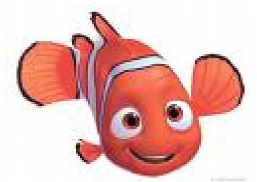






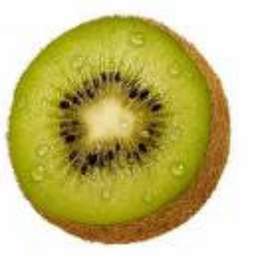




Fruit Pictures:



















Animal Picture:















Appendix 6: Instructions for off line study.

Favourite Task.

Slide 1

Welcome!

You are going to see some pictures,

one in each corner of the screen.

At the top of the screen a sentence will appear, it will ask you to name each of the pictures and choose which one is your favourite.

Please name the objects on the screen first before saying your favourite.

Press SPACE BAR to continue.

Slide 2

You may see some pictures more than once but this is not a memory test.

Please name the pictures and then choose your favourite one from the four presented in front of you.

Press SPACE BAR to continue.

Also changed the sentence at the top of the screen to read : Which picture is your favourite? – as discussed yesterday.

Last slide

The end.

Practice – off line.

Slide 1

Welcome.

Below is a face that you will see in the middle of the screen throughout this task.

(yellow face)

Slide 2

You are going to see some pictures,

one in each corner of the screen.

In the centre of the screen there will be a face.

At the top of the screen a sentence will appear, it will ask you to say which picture the face LIKES BEST.

Slide 3

Please wait until the face turns GREEN before saying the name of the picture that the face LIKES BEST.

Only say the name of the picture when the face turns GREEN!

(green face)

Slide 4

Please only say the name of one picture, the picture that the face LIKE BEST!

A cross will be flashed in the centre of the screen in between each presentation.

When you see a red circle please rest and wait for the next presentation.

You will only have a short period of time to make your decision so please make it quickly.

Slide 5

Please wait until the face has turned GREEN before saying your answer.

Remain silent at all other times in the task.

Please try to respond as quickly as possible once the face has turned GREEN.

Sentence at top of screen: Which picture does the face like best?

Practice-scanner.

Slide 1

Welcome.

Below is a face that you will see in the middle of the screen throughout this task.

(yellow face).

Slide 2

You are going to see some pictures,

one in each corner of the screen.

In the centre of the screen there will be a face.

At the top of the screen a sentence will appear, it will ask you to say which picture the face LIKES BEST.

Slide 3

When the face is yellow you will hear the noise of the scanner. But when the face turns GREEN the scanner will be silent and at this time you should say which picture the face LIKES BEST.

Only say the name of the picture when the face turns GREEN!

(green face)

Slide 4

Please only say the name of one picture, the picture that the face LIKES BEST!

A cross will be flashed in the centre of the screen in between each presentation.

When you see a red circle please rest and wait for the next presentation.

You will only have a short period of time to make your decision so please make it quickly.

Slide 5

Please remain as still as possible throughout the task.

Please wait until the face has turned GREEN before saying your answer.

Remain silent at all other times in the task.

Please try to respond as quickly as possible once the face has turned GREEN.

Like Best- off line.

Slide 1

Welcome

The instructions are the same as in the practice task.

You will see some pictures,

one in each corner of the screen.

A face will be in the middle of the screen.

At the top of the screen a sentence will appear, it will ask you to say which picture the face LIKES BEST.

As before please wait until the face turns GREEN before saying the name of the picture that the face LIKES BEST.

Slide 2

Please only say the name of one picture, the picture that the face LIKE BEST!

You will only have a short period of time to make your decision so please make it quickly.

Remain silent at all other times in the task.

Please try to respond as quickly as possible once the face has turned GREEN.

Sentence at the top: Which picture does the face like best?

Like best- scanner.

Slide 1

Welcome

The instructions are the same as in the practice task.

You will see some pictures,

one in each corner of the screen.

A face will be in the middle of the screen.

At the top of the screen a sentence will appear, it will ask you to say which picture the face LIKES BEST.

Slide 2

As before you will hear the noise of the scanner when the face is yellow. But when the face turns GREEN the scanner will be silent and at this time you should say which picture the face LIKES BEST.

Please only say the name of one picture, the picture that the face LIKES BEST!

You will only have a short period of time to make your decision so please make it quickly.

Slide 3

Please remain as still as possible throughout the task.

Remain silent at all other times in the task.

Please try to respond as quickly as possible once the face has turned GREEN.

When you see a red circle please rest and wait for the next presentation.

End slide

Please remain still and silent.

The next part of the task shall commence shortly.

Looking at.- offline.

Slide 1

Welcome

As before one you will see four pictures,

one in each corner of the screen.

A face will be in the middle of the screen.

At the top of the screen a sentence will appear, it will ask you to say which picture the face is LOOKING AT?

Slide 2

As before please wait until the face has turned GREEN before saying the name of the picture that the face is LOOKING AT!

Only say the name of the picture when the face turns GREEN!

Please only say the name of one picture, the picture that the face is LOOKING AT!

As before you will only have a short period of time to make your decision so please make it quickly.

Slide 3

A cross will be flashed in the centre of the screen in between each presentation.

When you see a red circle please rest and wait for the next presentation.

Please wait until the face has turned GREEN before saying your answer.

Remain silent at all other times in the task.

Please try to respond as quickly as possible once the face has turned GREEN.

Looking at- scanner.

Slide 1

Welcome

As before one you will see four pictures,

one in each corner of the screen.

A face will be in the middle of the screen.

At the top of the screen a sentence will appear, it will ask you to say which picture the face is LOOKING AT?

Slide 2

As before you will hear the noise of the scanner when the face is yellow. But when the face turns GREEN the scanner will be silent and at this time you should say which picture the face is LOOKING AT.

Only say the name of the picture when the face turns GREEN!

Please only say the name of one picture, the picture that the face is LOOKING AT!

Slide 3

As before you will only have a short period of time to make your decision so please make it quickly.

When you see a red circle please rest and wait for the next presentation.

Please wait until the face has turned GREEN before saying your answer.

Please try to respond as quickly as possible once the face has turned GREEN**.**

End Slide

This is the end of the task.

Please remain still and silent until instructed to move.

Thank- you for taking part.

Appendix 7: Information Sheet and Consent form for fMRI study.

Psychology

SCHOOL OF PHILOSOPHY, PSYCHOLOGY and LANGUAGE SCIENCES

The University of Edinburgh

7 George Square

Edinburgh

EH8 9JZ

Telephone 0131 650 3440

Direct Line to Dr Abrahams: 0131 650 3339

Email: Psychology@ed.ac.uk

Email Dr Abrahams: s.abrahams@ed.ac.uk

VOLUNTEER INFORMATION SHEET

Study title: "Neural Basis of Theory of Mind": An fMRI study

Thank- you for the interest in this work.

You are being invited to take part in a research study. Before you decide it is vital that you understand why the research is being done and what it will involve. Please take the time to read the following information and ensure that you understand all aspects involved, you can discuss this with other if you so wish. Ask if there is information that seems unclear or if you would like more information. Take time to decide whether or not you want to take part.

What is the purpose of the study?

Some neurological conditions can result in changes in emotions and behaviour, it is still unclear what regions of the brain are associated with these changes. To understand these changes important to gather information off healthy individuals, in particular considering the reason behind these changes and the brain regions associated with these changes. Hence in this study fMRI will be used to collect images of the brain whilst you conduct tasks. These

tasks represent the reason why emotion and social changes in patients may occur, and so hopefully will highlight the regions of the brain which are involved in this process. The tasks are simple, as you will be asked to view a series of objects from which you will have to choose one according to instructions given at beginning.

Why I have been chosen?

We will be seeing a between 10-16 control participants.

Do I have to take part?

It is completely your decision whether or not you take part in the above experiment. If you do decide to take part you shall be asked to keep this consent form and asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

If you decide to take part in the study you will be asked several background questions.

You will asked to attend an appointment at the University of Edinburgh Imaging Research Centre, Department of Clinical Neurosciences at Western General Hospital to undergo a functional Magnetic Resonance Imaging (fMRI) brain scan. The scan will last approximately 45 minutes and provides us with pictures of your brain. You will not be required to visit your GP. During the scan you will be perform a task.

You will be asked to lie on the scanner bed for around 45 minutes. While you are in the scanner, a series of pictures of our brain will be taken whilst conducting tasks. The tasks are very simple eye gaze tasks and you shall verbally indicate your answer when in instructed to by the screen. You will reimbursed for our time with £20.00

Whilst in the scan your responses will be recorded but these responses will be confidential.

What do I have to do?

You do not have to take any medication or undergo any invasive procedure whatsoever.

During your scanning session, you will simply need to lie as still in the scanner whilst completing a couple of tasks, during which time the scanner will be acquiring pictures. The

scanner itself makes a loud clicking noise while it operates. For your comfort, you will be provided with ear plugs or headphones.

What are the possible disadvantages and risks of taking part?

MRI uses a combination of powerful magnets and radio waves to create very high quality images of your brain. We do not anticipate any health risks from taking part in this study. MRI does not use X-rays, and no drugs or injections will be involved. It you agree to join the study, we will check that it is perfectly safe for you to be scanned. A long as people with any magnetic metal implants are excluded from the study (such as heart pacemarkers or metal clips in the brain), there are no known risks. In addition, there are no after effects of the scan.

This research is designed to improve knowledge of how the brain works, and are not for diagnostic or clinical purposes. However, a consultant radiologist will examine these scans and a report will be sent either to you GP or the Principle Investigator of the study. You may therefore need to give your GP's name and address to the person who has recruited you into the study.

You should be aware that there is a small possibility (about 3%) of a significant abnormality being detected in your scan, which may need to be acted upon, or GP told about, in case of any future illness. The study investigator or research centre Radiologist will be happy to discuss this further with you if you so wish.

If you feel distressed at any time during the process, it is important that you let the experimenter know straight away. If you feel distressed after the experiment, please contact Dr. Sharon Abrahams 0131 650 3339.

Pregnancy

Because MRI uses radiofrequencies and magnetic fields, pregnant women are not routinely scanned for research purposes. Pregnant women must not therefore take part in this study; neither should women who plan to become pregnant during the study. Any women who finds that she has become pregnant before taking part in the study should immediately tell her research doctor.

What are the possible benefits of taking part?

There will be no direct benefit to you by taking part, and your individual results will not be revealed to you. However, it is hoped that the research will improve the understanding of the changes in emotions and behaviour that individuals with different disorders experience and may influence care practices in the future.

What if something goes wrong?

Whilst we do not anticipate any adverse effects from taking part in the study, if you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for legal action but you have to pay for it. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, the normal National Health Service complaints mechanisms should be available to you.

Will my taking part in this study be kept confidential?

All the information collected about you will be kept strictly confidential. Any information about you will have your name and corresponding information removed so that you cannot be recognised from it.

What will happen to the results of the research study?

The results will be involved in a MSc research project.

Who is organising the research?

The study is being organised an MSc student, Nicola Elder who is currently attending Edinburgh University and Dr. Sharon Abrahams from the University of Edinburgh and Lothian Clinical Neuropsychology Unit at the Royal Edinburgh Hospital.

Who has reviewed the study?

This study has been reviewed by ethics committee in the NHS and the Psychology department of Edinburgh University.

Contact for further information

If you wish to ask anything further, please contact Dr. Sharon Abrahams via the address below:

Department of Psychology, PPLS

7 George Square

Edinburgh,

EH8 9JZ.

OR via the following telephone numbers or email addresses:

Dr. Abrahams on 0131 650 3339 (s.abrahams@ed.ac.uk)

Thank you for reading this information sheet. You will be given a copy to keep. If you have understood the contents of this sheet and wish to take part, please complete the consent sheet on the next page. If you have any questions feel free to ask them now.

CONSENT FORM- Confidential

Title of project: Neural Basis of Theory of Mind: An fMRI study

Name of Researcher: Nicola Elder *Please initial box*

5. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐
6. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
7. I understand that my voice will be audio taped for the purpose of the study. ☐
8. I agree to take part in this above study. ☐

Name of Participant	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

Appendix 8 : Screening Scanning Form.

SFC BRAIN IMAGING RESEARCH CENTRE

SCREENING FORM FOR PATIENTS (#1-P)

Surname: First name(s):

Home address:

Date of birth: contact telephone number: Weight

- Do you have a **cardiac pacemaker** or artificial **heart valve**? **YES/NO**
- Have you **ever** had any operations on your **chest, heart, head,** or **eyes**? **YES/NO**
- Do you have any **vascular clips**, a **cochlear implant** or a **shunt**? **YES/NO**
  If you have a shunt, is it programmable? _____
- Have you **ever** had an incident involving **metal fragments** penetrating your eye or any part of your **body**? **YES/NO**
- Do you wear **dentures**, a **dental plate**, a **brace, hearing aid** or **coloured** contact lenses? **YES/NO**
- Do you have a **heart condition, asthma** or **kidney disorder**? **YES/NO**
- Are you wearing a **cardiac, HRT** or **nicotine patch**? **YES/NO**
- Do you suffer from **epilepsy** or **diabetes**? **YES/NO**
- Have you had any **recent surgery** of any type **(within the last six months)**? **YES/NO**
- Do you have any **metal** or **electrical** objects in your body that you cannot remove, e.g. body piercings, shrapnel or stimulators? **YES/NO**

LADIES: Could you be **pregnant?** Or are you **breast- feeding?** **YES/NO**

Reasons why it might not be safe for me to undergo Magnetic Resonance Imaging scanning have been explained to me, and I have been given the opportunity to ask questions about them. I am satisfied that I have all the information that I need to provide **informed consent**.
I confirm I have removed all metallic objects from my person.

Signature of Patient (or Guardian): Date:

Name of Radiographer: CN Number (SBIRCS use only):

Appendix 9: Instructions for the three conditions within FMRI study.

Favourite Task Condition- top sentence: Which picture is your favourite?

Slide1

Welcome!

You are going to see some pictures,

one in each corner of the screen.

At the top of the screen a sentence will appear, it will ask you to say which picture is your favourite.

There will be a circle in the middle of screen.

Slide 2

When the circle is YELLOW you will hear the noise of the scanner. But when the circle turns GREEN the scanner will be silent and at this time you should say which picture is your favourite.

Only say one name, and only speak when the face turns GREEN and the scanner is silent!

You may see some pictures more than once but this is not a memory test.

You will only have a short period of time to make your decision so please make it quickly.

Slide 3

A cross will be flashed in the centre of the screen in between each presentation.

When you see a red circle please rest and wait for the next presentation.

Please remain still as possible throughout the task.

Please remain silent at all other times in the task.

End slide

This is the end of this part of the task.

Please remain still and silent as the next task shall begin shortly.

Like Best Condition: Top sentence: Which picture does the face like best?

Slide 1

In the next scans a face will appear in the centre of the screen.

(Below this sentence the yellow face with eyes facing straight forward should show.)

Slide 2

As before you will see some pictures,

one in each corner of the screen.

A face will be in the middle of the screen.

At the top of the screen a sentence will appear, it will ask you to say which picture the face LIKES BEST.

Slide 3

When the face is YELLOW you will hear the noise of the scanner. But when the face turns GREEN the scanner will be silent and at this time you should say which picture the face LIKES BEST.

Only say one name, and only speak when the face turns GREEN and the scanner is silent!

(Below this the green face with eyes looking straight forward should show.)

Slide 4

A cross will be flashed in the centre of the screen in between the presentation.

When you see a red circle please rest and wait for next presentation.

You will only have a short period of time to make your decision so please make it quickly.

Slide 5

Please remain as still as possible throughout the task.

Remain silent at all other times in the task.

Please wait until the face had turned GREEN before saying your answer.

End slide

Please remain still and silent.

The next part of the task shall commence shortly.

Looking at condition: top sentence: Which picture is the face looking at?

Slide 1

Welcome

As before one you will see four pictures,

one in each corner of the screen.

A face will be in the middle of the screen.

At the top of the screen a sentence will appear, it will ask you to say which picture the face is LOOKING AT?

Slide 2

As before you will hear the noise of the scanner when the face is yellow. But when the face turns GREEN the scanner will be silent and at this time you should say which picture the face is LOOKING AT.

Only say the name of the picture when the face turns GREEN!

Please only say the name of one picture, the picture that the face is LOOKING AT!

Slide 3

As before you will only have a short period of time to make your decision so please make it quickly.

When you see a red circle please rest and wait for the next presentation.

Please wait until the face has turned GREEN before saying your answer.

Please try to respond as quickly as possible once the face has turned GREEN.

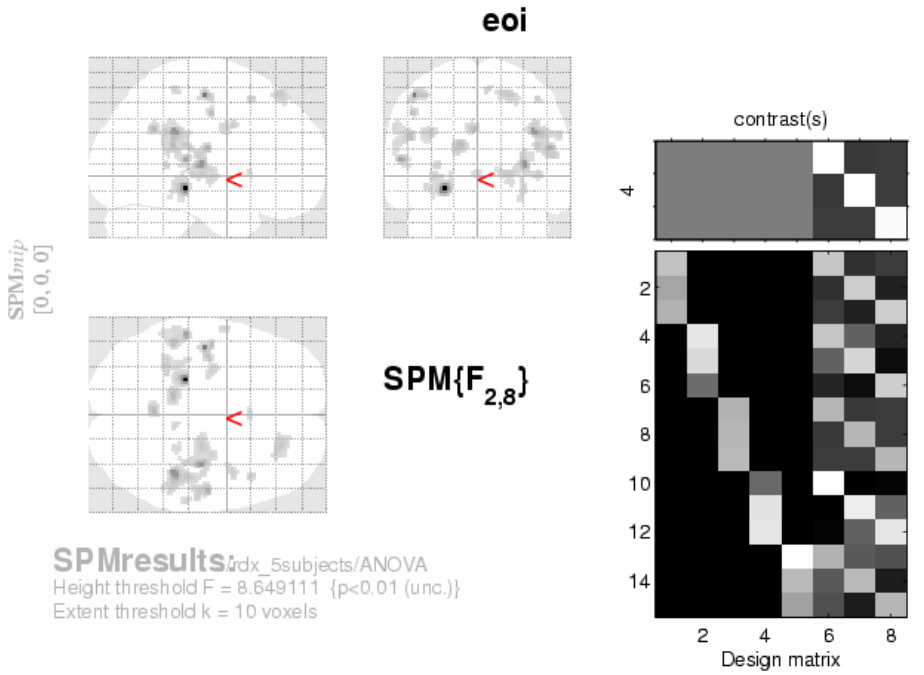
End slide

This is the end of the task.

Please remain still and silent until instructed to move.

Thank- you for taking part.

Appendix 10: Output from brain imaging analysis.



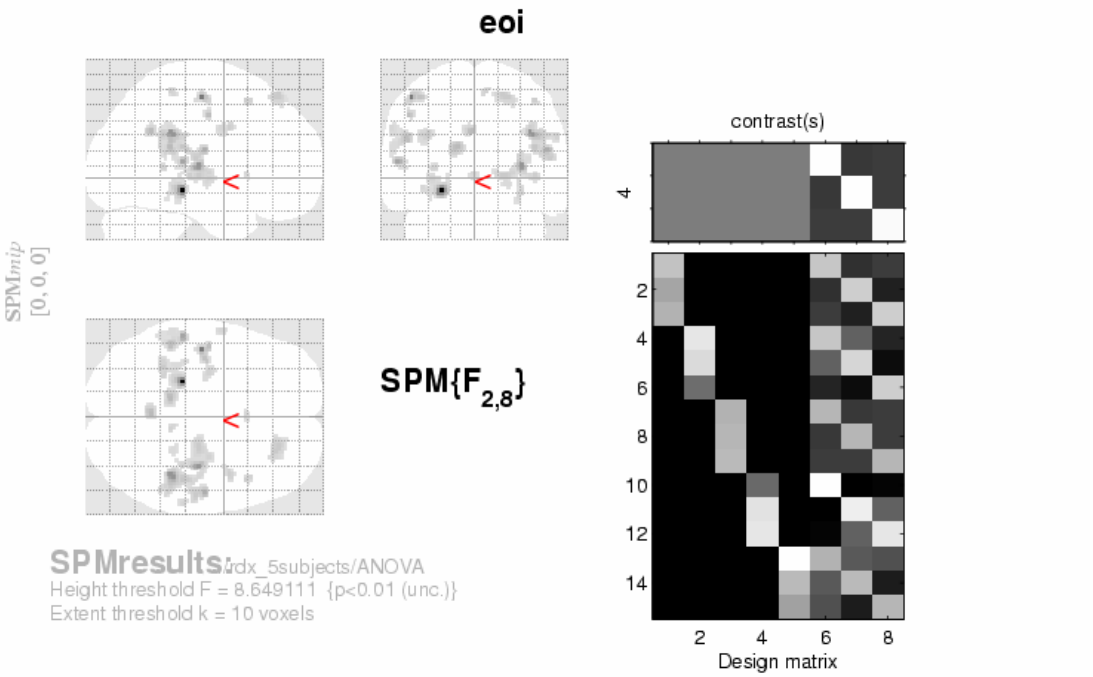
Statistics: ***p–values adjusted for search volume***

set–level		cluster–level				peak–level					mm mm mm	
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	F	$(Z_=)$	p_{uncorr}		
	22			142		0.050	0.353	148.29	4.90	0.000	−24	−30 −8
						1.000	0.998	14.65	2.86	0.002	−38	−28 −6
						1.000	0.998	13.18	2.76	0.003	−32	−38 −10
				52		0.807	0.788	71.69	4.32	0.000	−46	−16 56
				204		0.957	0.788	53.87	4.08	0.000	34	−18 10
						1.000	0.998	21.27	3.23	0.001	20	−18 2
						1.000	0.998	18.88	3.11	0.001	44	−24 2
				274		0.962	0.788	52.89	4.06	0.000	40	−38 32
						0.998	0.998	39.33	3.80	0.000	52	−14 20
						1.000	0.998	24.24	3.35	0.000	44	−30 22
				39		0.994	0.998	43.47	3.89	0.000	−56	−30 12
						1.000	0.998	9.63	2.44	0.007	−50	−34 8
				46		1.000	0.998	32.71	3.63	0.000	−2	−52 32
				67		1.000	0.998	30.72	3.57	0.000	−12	−38 22
				145		1.000	0.998	29.54	3.54	0.000	−50	−38 28
						1.000	0.998	12.57	2.71	0.003	−58	−38 22
						1.000	0.998	11.08	2.58	0.005	−58	−40 36
				15		1.000	0.998	29.27	3.53	0.000	−48	−10 44
				59		1.000	0.998	22.64	3.29	0.001	22	40 56
				54		1.000	0.998	22.13	3.26	0.001	−34	−44 30
				28		1.000	0.998	19.36	3.14	0.001	40	4 36
				10		1.000	0.998	19.02	3.12	0.001	44	16 54
				46		1.000	0.998	17.58	3.04	0.001	−30	−10 0

table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 8.65, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 14.967
Expected number of clusters, <c> =
FWEp: 148.614, FDRp: Inf

Degrees of freedom = [2.0, 8.0]
FWHM = 11.6 11.4 10.7 mm mm mm; 5.8 5.7 5.3 {voxels}
Volume: 847616 = 105952 voxels = 544.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 176.40 voxels)
Page 1



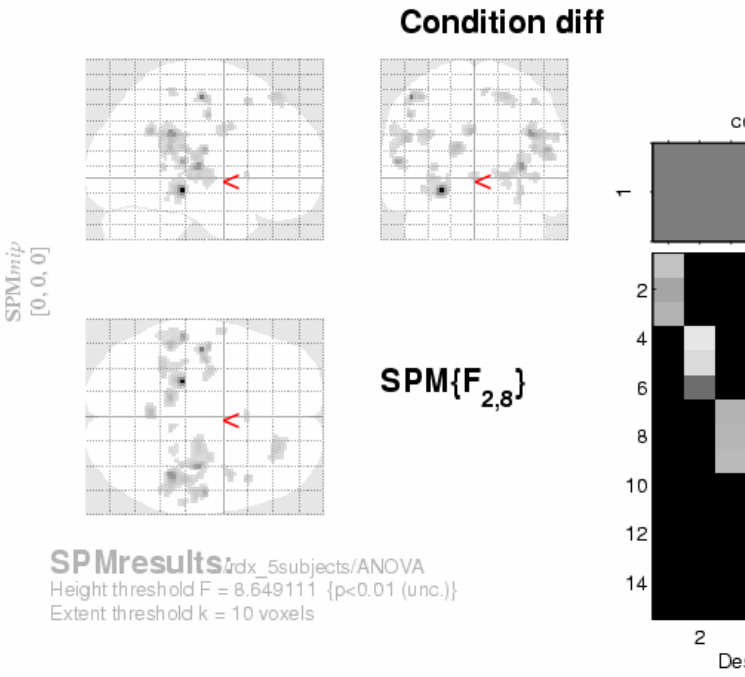
Statistics: ***p–values adjusted for search volume***

set–level		cluster–level				peak–level					mm mm mm
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	F	$(Z_=)$	p_{uncorr}	
				10		1.000	0.998	17.50	3.04	0.001	8 −38 60
				12		1.000	0.998	17.08	3.01	0.001	60 −28 28
				10		1.000	0.998	16.50	2.98	0.001	−28 −44 8
				16		1.000	0.998	15.80	2.94	0.002	34 −30 −10
						1.000	0.998	9.89	2.46	0.007	30 −34 −16
				11		1.000	0.998	15.54	2.92	0.002	−2 16 4
				20		1.000	0.998	15.24	2.90	0.002	−60 −2 34
				11		1.000	0.998	11.96	2.66	0.004	22 −36 −4
				10		1.000	0.998	11.32	2.60	0.005	40 −34 14

table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 8.65, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 14.967
Expected number of clusters, <c> =
FWEp: 148.614, FDRp: Inf

Degrees of freedom = [2.0, 8.0]
FWHM = 11.6 11.4 10.7 mm mm mm; 5.8 5.7 5.3 {voxels}
Volume: 847616 = 105952 voxels = 544.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 176.40 voxels)
Page 2/2



Statistics: ***p–values adjusted for search volume***

set–level		cluster–level				peak–level					mm mm mm		
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	F	$(Z_=)$	p_{uncorr}			
				10		1.000	0.998	17.50	3.04	0.001	8	-38	60
				12		1.000	0.998	17.08	3.01	0.001	60	-28	28
				10		1.000	0.998	16.50	2.98	0.001	-28	-44	8
				16		1.000	0.998	15.80	2.94	0.002	34	-30	-10
						1.000	0.998	9.89	2.46	0.007	30	-34	-16
				11		1.000	0.998	15.54	2.92	0.002	-2	16	4
				20		1.000	0.998	15.24	2.90	0.002	-60	-2	34
				11		1.000	0.998	11.96	2.66	0.004	22	-36	-4
				10		1.000	0.998	11.32	2.60	0.005	40	-34	14

table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 8.65, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 14.967
Expected number of clusters, <c> =
FWEp: 148.614, FDRp: Inf

Degrees of freedom = [2.0, 8.0]
FWHM = 11.6 11.4 10.7 mm mm mm; 5.8 5.7 5.3 {voxels}
Volume: 847616 = 105952 voxels = 544.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 176.40 voxels)
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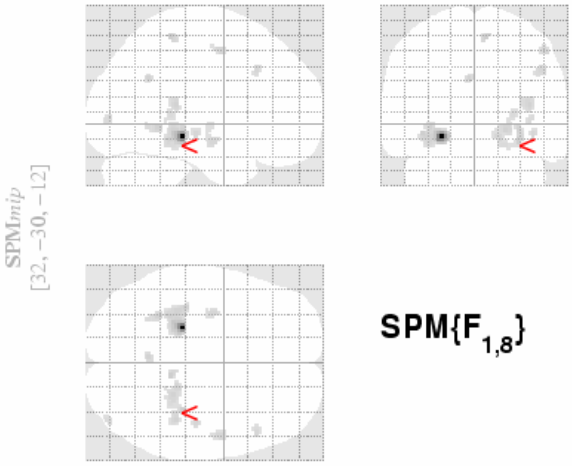
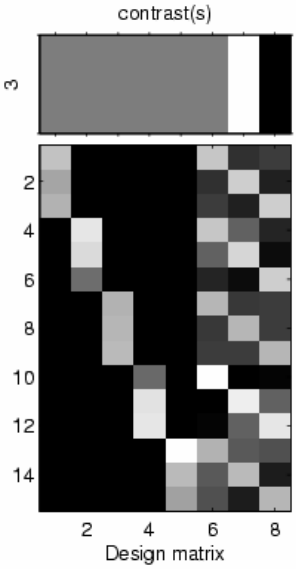
like best vs look at





SPMresults: /rdx_5subjects/ANOVA
Height threshold F = 11.258624 {p<0.01 (unc.)}
Extent threshold k = 10 voxels

Statistics: ***p–values adjusted for search volume***

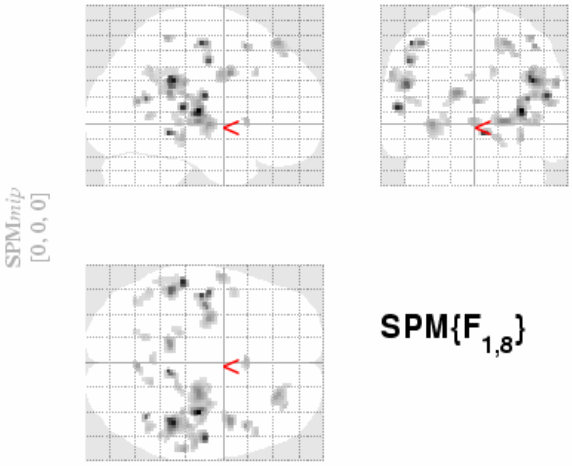
set–level		cluster–level				peak–level					mm mm mm		
p	*c*	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	*F*	$(Z_=)$	p_{uncorr}			
	12			203		0.041	0.164	224.78	4.94	0.000	−24	−30	−8
						1.000	0.981	27.81	3.17	0.001	−38	−28	−6
						1.000	0.981	25.44	3.09	0.001	−32	−38	−10
				13		1.000	0.981	28.90	3.21	0.001	8	−38	60
				98		1.000	0.981	26.89	3.14	0.001	32	−30	−12
						1.000	0.981	22.72	2.99	0.001	22	−36	−4
						1.000	0.981	16.49	2.69	0.004	20	−40	−14
				12		1.000	0.981	23.18	3.00	0.001	−4	−54	32
				19		1.000	0.981	22.75	2.99	0.001	−32	−48	−2
				43		1.000	0.981	22.58	2.98	0.001	40	−34	14
				35		1.000	0.981	22.07	2.96	0.002	−34	−6	−12
						1.000	0.981	14.55	2.57	0.005	−32	−10	−2
				16		1.000	0.981	21.77	2.95	0.002	52	−2	50
				14		1.000	0.981	20.76	2.90	0.002	50	24	38
				10		1.000	0.981	20.05	2.87	0.002	42	−20	−6
				12		1.000	0.981	17.60	2.75	0.003	40	−84	4
				24		1.000	0.981	17.21	2.73	0.003	28	−38	8

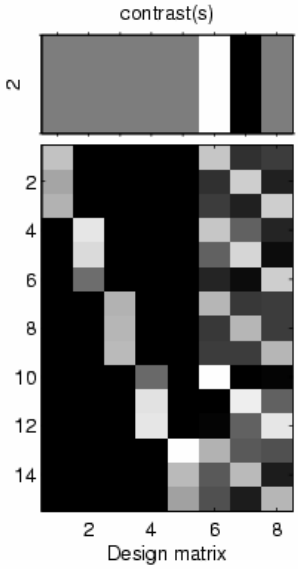
table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 11.26, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 18.445
Expected number of clusters, <c> =
FWEp: 213.530, FDRp: Inf

Degrees of freedom = [1.0, 8.0]
FWHM = 11.6 11.4 10.7 mm mm mm; 5.8 5.7 5.3 {voxels}
Volume: 847616 = 105952 voxels = 544.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 176.40 voxels)

favorite vs like best





SPMresults: /idx_5subjects/ANOVA
Height threshold F = 11.258624 {p<0.01 (unc.)}
Extent threshold k = 10 voxels

Statistics: *p–values adjusted for search volume*

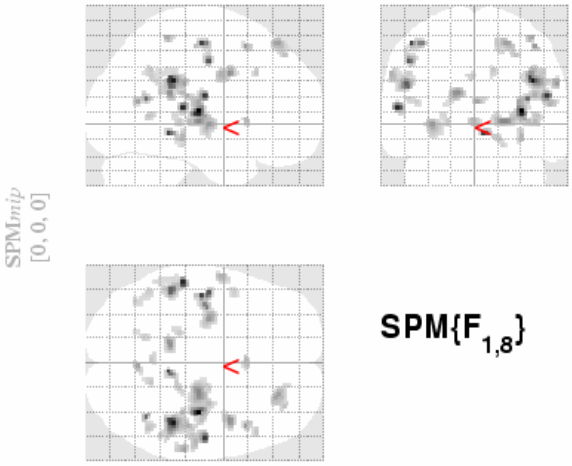
set–level		cluster–level				peak–level					mm mm mm		
p	*c*	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	*F*	($Z_=$)	p_{uncorr}			
	27			288		0.816	0.774	90.07	4.21	0.000	34	-18	10
						1.000	0.946	41.18	3.53	0.000	20	-18	2
						1.000	0.946	24.79	3.07	0.001	44	-24	2
				290		0.888	0.774	80.27	4.12	0.000	42	-36	30
						0.960	0.774	67.46	3.97	0.000	52	-14	20
						1.000	0.946	29.00	3.21	0.001	44	-26	20
				40		0.927	0.774	74.07	4.05	0.000	-56	-30	12
				34		0.970	0.774	64.82	3.93	0.000	6	-40	-6
						1.000	0.946	19.94	2.86	0.002	18	-32	-10
				85		0.973	0.774	63.84	3.92	0.000	-46	-16	56
						0.988	0.813	58.04	3.84	0.000	-48	-10	44
						1.000	0.946	43.70	3.59	0.000	-38	-12	56
				149		0.994	0.825	54.10	3.78	0.000	-50	-38	28
						1.000	0.946	14.28	2.55	0.005	-58	-36	36
						1.000	0.946	13.88	2.52	0.006	-56	-48	30
				16		0.997	0.834	50.84	3.72	0.000	38	-56	18
				60		1.000	0.946	38.62	3.48	0.000	40	4	36
				53		1.000	0.946	38.18	3.46	0.000	-12	-38	22
				105		1.000	0.946	35.15	3.39	0.000	-30	-10	0
				27		1.000	0.946	34.10	3.36	0.000	60	-28	28
				12		1.000	0.946	33.67	3.35	0.000	44	16	54
				57		1.000	0.946	32.52	3.32	0.000	22	40	56
						1.000	0.946	21.21	2.92	0.002	30	44	48

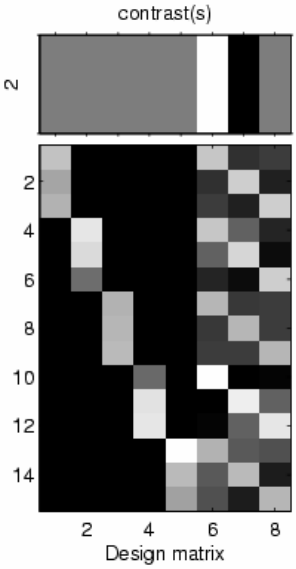
table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 11.26, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 18.445
Expected number of clusters, <c> =
FWEp: 213.530, FDRp: Inf

Degrees of freedom = [1.0, 8.0]
FWHM = 11.6 11.4 10.7 mm mm mm; 5.8 5.7 5.3 {voxels}
Volume: 847616 = 105952 voxels = 544.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 176.40 voxels)

favorite vs like best





SPMresults: /rdx_5subjects/ANOVA
Height threshold F = 11.258624 {p<0.01 (unc.)}
Extent threshold k = 10 voxels

Statistics: ***p–values adjusted for search volume***

set–level		cluster–level				peak–level					mm mm mm		
p	*c*	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	*F*	$(Z_=)$	p_{uncorr}			
				13		1.000	0.946	31.03	3.28	0.001	2	−62	16
				18		1.000	0.946	29.80	3.24	0.001	42	−40	60
				39		1.000	0.946	27.39	3.16	0.001	−60	−2	34
				14		1.000	0.946	25.79	3.10	0.001	34	−30	−10
				17		1.000	0.946	25.79	3.10	0.001	−2	16	4
				30		1.000	0.946	20.95	2.91	0.002	46	−54	6
				19		1.000	0.946	20.46	2.89	0.002	14	−52	38
				11		1.000	0.946	19.70	2.85	0.002	48	24	36
				11		1.000	0.946	18.81	2.81	0.002	−2	−52	34
				21		1.000	0.946	18.47	2.79	0.003	16	−12	56
				23		1.000	0.946	18.10	2.77	0.003	−20	−32	2
				13		1.000	0.946	17.74	2.75	0.003	−48	8	36
				19		1.000	0.946	17.52	2.74	0.003	−18	−56	18
						1.000	0.951	13.46	2.49	0.006	−22	−64	14
				30		1.000	0.946	17.05	2.72	0.003	−48	−54	18
						1.000	0.946	16.66	2.70	0.004	−42	−64	16

table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 11.26, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 18.445
Expected number of clusters, <c> =
FWEp: 213.530, FDRp: Inf

Degrees of freedom = [1.0, 8.0]
FWHM = 11.6 11.4 10.7 mm mm mm; 5.8 5.7 5.3 {voxels}
Volume: 847616 = 105952 voxels = 544.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 176.40 voxels)
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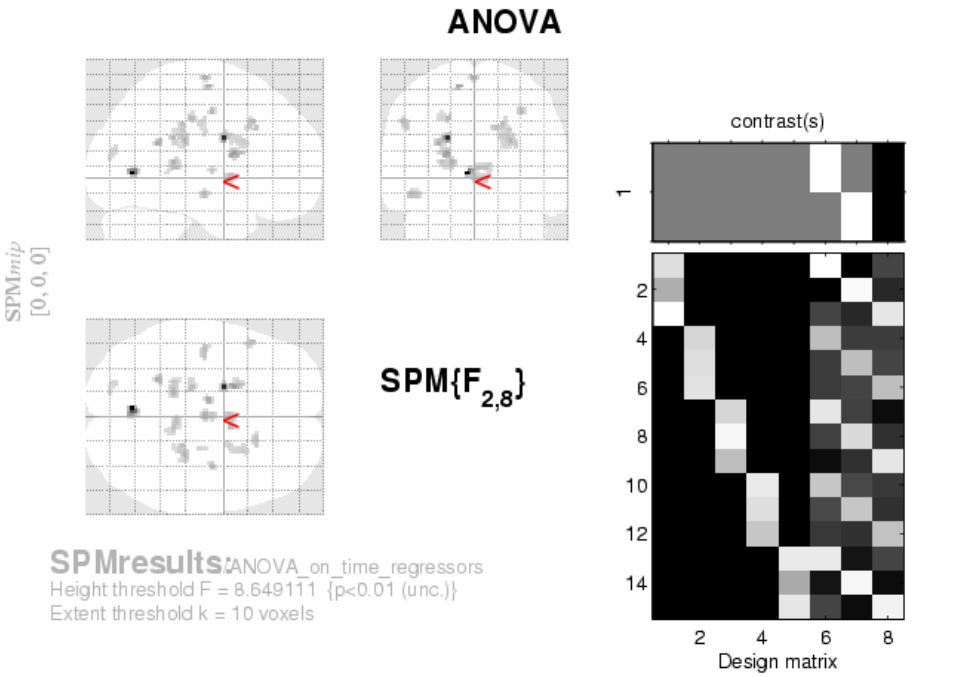


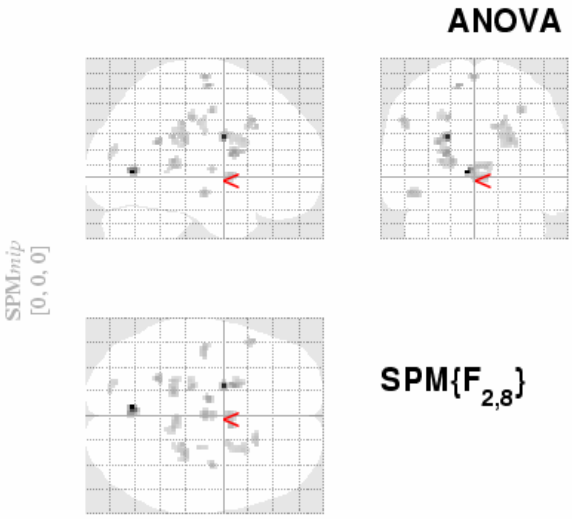
Statistics: ***p–values adjusted for search volume***

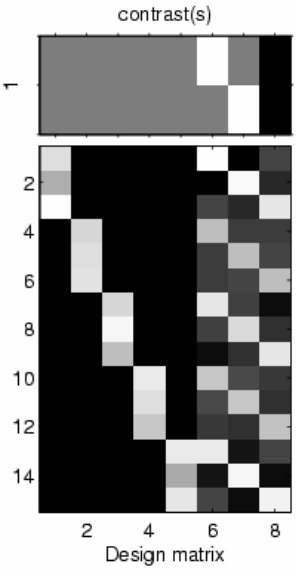
set–level		cluster–level				peak–level					mm mm mm		
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	F	$(Z_=)$	p_{uncorr}			
	20			32		0.948	0.995	56.23	4.11	0.000	−6	−66	4
				23		0.989	0.995	46.32	3.94	0.000	−20	0	28
				25		1.000	0.995	22.62	3.29	0.001	−20	8	18
				11		1.000	0.995	19.73	3.15	0.001	−12	−10	64
				15		1.000	0.995	18.96	3.11	0.001	0	−14	70
				13		1.000	0.995	18.77	3.10	0.001	−26	−48	24
				41		1.000	0.995	18.24	3.08	0.001	−16	−36	12
				64		1.000	0.995	18.12	3.07	0.001	26	−28	26
						1.000	0.995	15.38	2.91	0.002	20	−30	38
						1.000	0.995	9.84	2.46	0.007	20	−36	32
				17		1.000	0.995	16.92	3.00	0.001	−20	−22	42
				24		1.000	0.995	16.61	2.99	0.001	−52	22	40
				42		1.000	0.995	16.57	2.98	0.001	8	6	0
						1.000	0.995	15.12	2.89	0.002	0	6	2
				14		1.000	0.995	16.39	2.97	0.001	−18	−36	28
				23		1.000	0.995	16.23	2.96	0.002	−46	−14	−10
				10		1.000	0.995	16.19	2.96	0.002	34	−8	46
				29		1.000	0.995	15.56	2.92	0.002	8	−36	8
				12		1.000	0.995	14.65	2.86	0.002	16	24	36
				12		1.000	0.995	14.19	2.83	0.002	−2	−8	6
				47		1.000	0.995	12.76	2.72	0.003	24	14	26
						1.000	0.995	12.48	2.70	0.003	20	4	28
				13		1.000	0.995	11.36	2.61	0.005	−22	−78	20
						1.000	0.995	10.27	2.50	0.006	−16	−82	14

table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 8.65, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 14.458
Expected number of clusters, <c> =
FWEp: 148.614, FDRp: Inf

Degrees of freedom = [2.0, 8.0]
FWHM = 11.5 11.6 10.2 mm mm mm; 5.8 5.8 5.1 {voxels}
Volume: 847616 = 105952 voxels = 563.7 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 170.40 voxels)





SPMresults: ANOVA_on_time_regressors
Height threshold F = 8.649111 {p<0.01 (unc.)}
Extent threshold k = 10 voxels

Statistics: ***p–values adjusted for search volume***

set–level		cluster–level				peak–level					mm mm mm		
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	F	$(Z_=)$	p_{uncorr}			
				13		1.000	0.995	11.16	2.59	0.005	22	−18	38

table shows 3 local maxima more than 8.0mm apart

Height threshold: F = 8.65, p = 0.010 (1.000)
Extent threshold: k = 10 voxels, p = ()
Expected voxels per cluster, <k> = 14.458
Expected number of clusters, <c> =
FWEp: 148.614, FDRp: Inf

Degrees of freedom = [2.0, 8.0]
FWHM = 11.5 11.6 10.2 mm mm mm; 5.8 5.8 5.1 {voxels}
Volume: 847616 = 105952 voxels = 563.7 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 170.40 voxels)
Page 2/2